CHEMISTRY

Team Kohinoor
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NEET

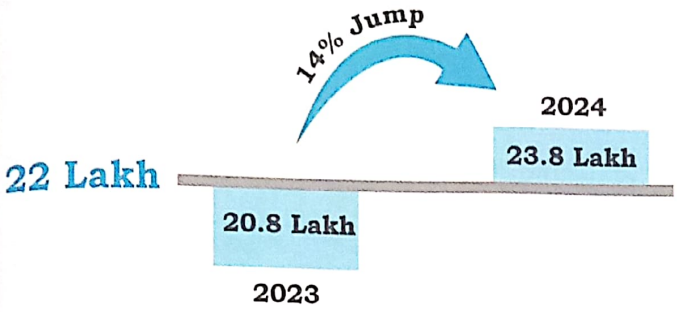
37 Years

(2024-1988)

CHAPTER & TOPIC-WISE SOLUTIONS

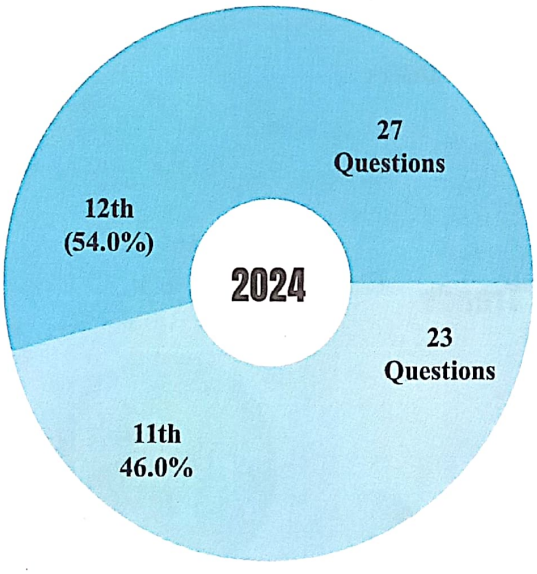
NEET BLUEPRINT: ANALYZING PATTERNS FOR EXAM MASTERY

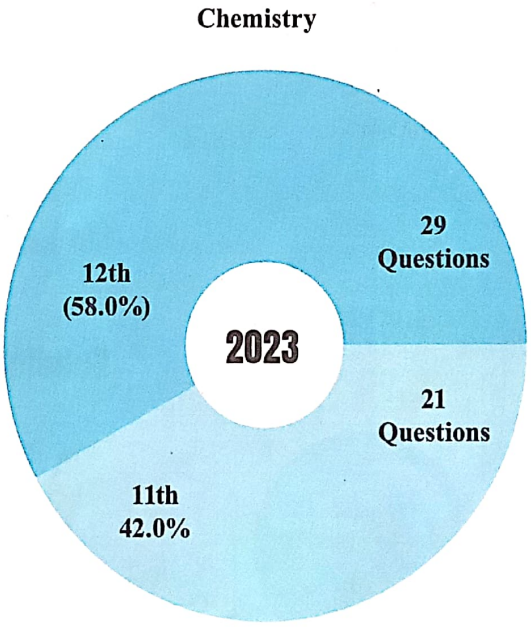
Registered Candidate Comparison



		2023	2024	
Female		11.8 Lakh	13.6 Lakh	
Male		9 Lakh	10.18 Lakh	

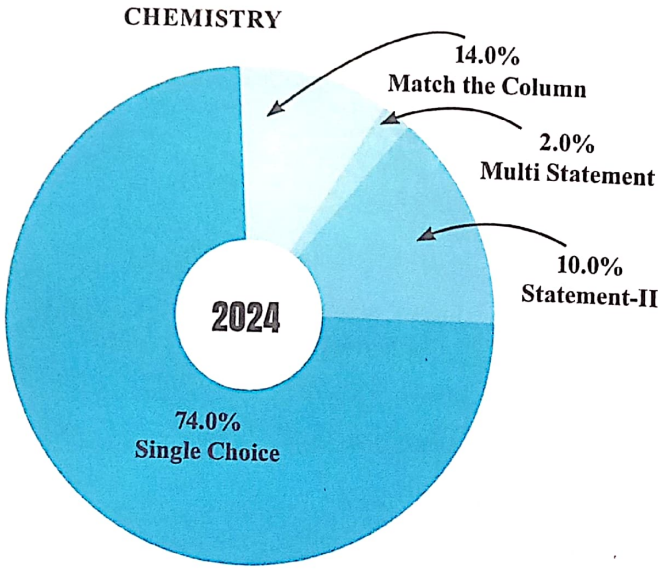
Class-wise Comparison

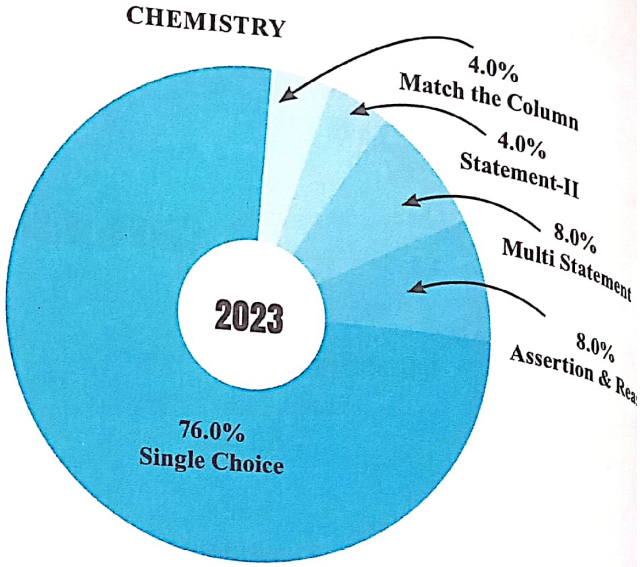




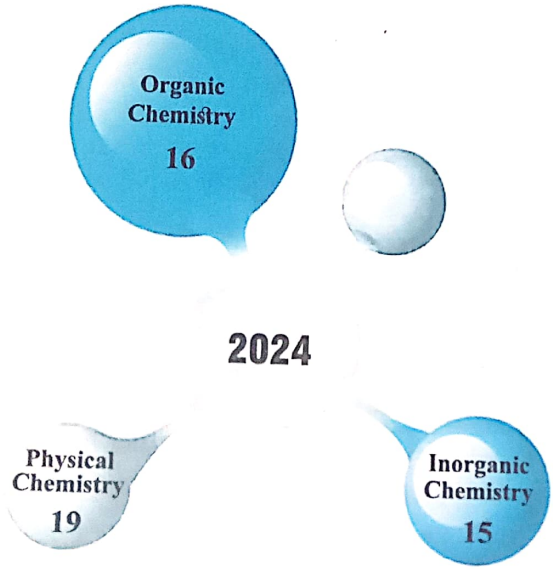
Question Type Analysis (NEET 2024)						
Subject	**Single Choice**	**Statement II**	**Multi Statement**	**Assertion & Reason**	**Match the Column**	**Grand Total**
Physics	44	1	2	1	2	50
Chemistry	37	5	1	0	7	50
Botany	24	5	8	0	13	50
Zoology	17	5	8	2	18	50
Total	**122**	**16**	**19**	**3**	**40**	**50**

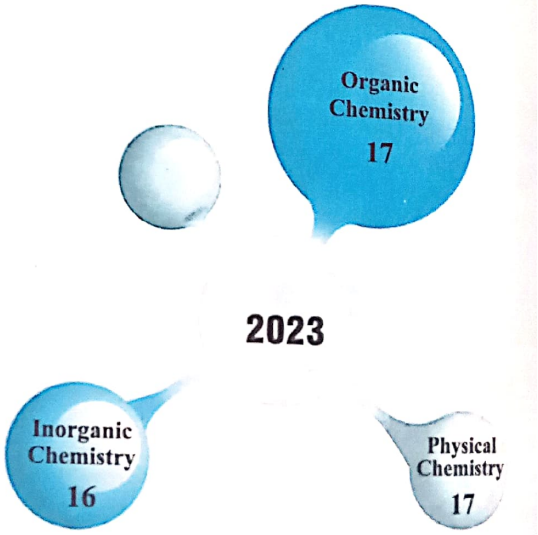
Question Type Analysis (NEET 2023)						
Subject	Single Choice	Statement II	Multi Statement	Assertion & Reason	Match the Column	Grand Total
Physics	48	2	0	0	0	50
Chemistry	38	2	4	4	2	50
Botany	33	3	4	5	5	50
Zoology	19	8	7	3	13	50
Total	**138**	**15**	**15**	**12**	**20**	**200**





Subdicipline Question Trends





YEAR WISE NUMBER OF QUESTIONS

Chemistry-XI

Year Wise Number of Questions

Chapters Name	2024	2023	2023 Manipur	2022	2022 Re	2021	2020	2020 Covid	2019	2018	2017	2016 II	2016 I	2015	2015 Re	2014
Some Basic Concepts of Chemistry	3	1	1	1	1	1	1	1	1	2	0	1	0	0	4	3
Structure of Atom	2	2	2	2	2	1	1	1	2	2	1	2	1	1	1	2
Classification of Elements and Periodicity in Properties	2	1	3	1	2	1	1	0	1	0	1	0	1	2	1	2
Chemical Bonding and Molecular Structure	3	2	2	2	2	3	2	3	2	1	2	5	2	5	1	3
Thermodynamics	3	1	1	1	1	2	2	2	2	1	2	1	2	1	0	1
Equilibrium	3	1	2	2	2	1	3	2	3	3	3	3	2	3	4	3
Redox Reactions	1	1	1	2	1	1	1	1	2	1	0	0	1	0	1	1
The p-Block Elements	0	2	1	2	2	0	3	1	2	2	1	2	0	0	1	0
Organic Chemistry-Some Basic Principles and Techniques	4	2	2	2	3	2	2	1	0	3	3	1	0	8	2	2
Hydrocarbons	2	2	1	3	2	4	2	2	4	2	3	6	4	2	3	3

Chemistry-XII

Year Wise Number of Questions

Chapters Name	2024	2023	2023 Manipur	2022	2022 Re	2021	2020	2020 Covid	2019	2018	2017	2016 II	2016 I	2015	2015 Re	2014
Solutions	2	1	1	2	1	2	2	2	2	0	2	2	2	3	1	1
Electrochemistry	2	2	3	2	2	2	2	2	2	1	0	5	1	1	0	4
Chemical Kinetics	3	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1
The p-Block Elements (Group 15 to 18)	2	2	0	2	2	2	2	4	3	4	3	1	5	1	4	1
The d and f-Block Elements	3	2	2	2	2	2	2	3	1	2	3	1	2	3	1	2
Coordination Compounds	3	2	2	2	2	2	1	1	1	3	3	2	1	2	4	2
Haloalkanes and Haloarenes	2	2	3	1	1	2	1	1	0	0	1	1	1	0	3	1
Alcohols, Phenols and Ethers	2	2	2	2	2	2	2	2	2	3	3	0	1	1	1	3
Aldehydes, Ketones and Carboxylic Acids	3	4	4	4	4	2	2	2	1	2	2	1	3	1	3	0
Amines	2	2	2	2	2	2	1	1	1	1	1	2	1	1	2	2
Biomolecules	1	1	1	1	1	1	2	2	1	2	0	2	3	0	0	2

Contents Cum Topic Weightage

The following abbreviations have been used in the book:

[MR*] - Must Revise Questions **[OS] - Outside NCERT Questions**

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7	Mole Concept and Molar Masses	1
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Class - XI

Team Kohinoor
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CHAPTER 1

Some Basic Concepts of Chemistry

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Significant Figures, Laws of Chemical Combinations

1. The density of the solution is 2.15 g mL^{-1}, then mass of 2.5 mL solution in correct significant figures is: *(2022 Re)*

a. 53.75 g
b. 5375×10^{-3} g
c. 5.4 g
d. 5.38 g

2. Equal masses of H_2, O_2 and methane have been taken in a container of volume V at temperature 27°C in identical conditions. The ratio of the volumes of gases H_2 : O_2 : methane would be: *(2014)*

a. 8 : 16 : 1
b. 16 : 8 : 1
c. 16 : 1 : 2
d. 8 : 1 : 2

3. Given the numbers, 161 cm, 0.161 cm, 0.0161 cm. The number of significant figures for the three numbers is: [**MR***] *(1998)*

a. 3, 4 and 5, respectively
b. 3, 4 and 4, respectively
c. 3, 3 and 4, respectively
d. 3, 3 and 3, respectively

4. The molecular weight of O_2 and SO_2 are 32 and 64 respectively. At 15°C and 150 mm Hg pressure, one litre of O_2 contains 'N' molecules. The number of molecules in two litres of SO_2 under the same conditions of temperature and pressure will be: *(1990)*

a. N/2
b. N
c. 2 N
d. 4 N

Atomic and Molecular Masses

5. Suppose the elements X and Y combine to form two compounds XY_2 and X_3Y_2. When 0.1 mole of XY_2 weighs 10 g and 0.05 mole of X_3Y_2 weighs 9 g, the atomic weights of X and Y are: *(2016)*

a. 20, 30
b. 30, 20
c. 40, 30
d. 60, 40

6. An element X, has the following isotopic composition:

^{200}X: 90% ^{199}X: 8.0% ^{202}X: 2.0%

The weighed average atomic mass of the naturally occurring element X is closest to: [**MR***] *(2007)*

a. 201 amu
b. 202 amu
c. 199 amu
d. 200 amu

7. 0.24 g of a volatile gas, upon vaporisation, gives 45 mL vapour at NTP. What will be the vapour density of the substance?

(Density of H_2 = 0.089 g/L): *(1996)*

a. 95.93
b. 59.93
c. 95.39
d. 5.993

8. Boron has two stable isotopes, ^{10}B(19%) and ^{11}B(81%). Calculate average atomic weight of boron in the periodic table: *(1990)*

a. 10.80
b. 10.2
c. 11.2
d. 10.0

Mole Concept and Molar Masses

9. Which one of the followings has maximum number of atoms? [**MR***] *(2020)*

a. 1 g of Mg(s) [Atomic mass of Mg = 24]
b. 1 g of O_2(g) [Atomic mass of O = 16]
c. 1 g of Li(s) [Atomic mass of Li = 7]
d. 1 g of Ag(s) [Atomic mass of Ag = 108]

10. One mole of carbon atom weighs 12g, the number of atoms in it is equal to. *(2020-Covid)*

(Mass of carbon- 12 is 1.9926×10^{-23} g)

a. 6.022×10^{22}
b. 12×10^{22}
c. 6.022×10^{23}
d. 12×10^{23}

11. In which case is number of molecules of water maximum? [**MR***] *(2018)*

a. 18 mL of water
b. 0.18 g of water
c. 10^{-3} mol of water
d. 0.00224 L of water vapours at 1 atm and 273 K

12. A mixture of gases contains H_2 and O_2 gases in the ratio of 1 : 4 (w/w). What is the molar ratio of the two gases in the mixture? *(2015)*

a. 16 : 1 b. 2 : 1
c. 1 : 4 d. 4 : 1

13. The number of water molecules is maximum in: *(2015 Re)*

a. 18 moles of water b. 18 molecules of water
c. 1.8 gram of water d. 18 gram of water

14. If Avogadro number N_A, is changed from 6.022×10^{23} mol^{-1} to 6.022×10^{20} mol^{-1}, this would change: *(2015 Re)*

a. The ratio of elements to each other in a compound
b. The definition of mass in units of grams
c. The mass of one mole of carbon
d. The ratio of chemical species to each other in a balanced equation

15. Which has the maximum number of molecules among the following? *(2011 Mains)*

a. 8 g H_2 b. 64 g SO_2
c. 44 g CO_2 d. 48 g O_3

16. The number of atoms in 0.1 mol of a triatomic gas is: ($N_A = 6.02 \times 10^{23}$ mol^{-1}): *(2010 Pre)*

a. 1.800×10^{22} b. 6.026×10^{22}
c. 1.806×10^{23} d. 3.600×10^{23}

17. The maximum number of molecules is present in: [MR*] *(2004)*

a. 5 L of N_2 gas at STP b. 0.5 g of H_2 gas
c. 10 g of O_2 gas d. 15 L of H_2 gas at STP

18. Which has maximum molecules? *(2002)*

a. 7 g N_2 b. 2 g H_2
c. 16 g NO_2 d. 16 g O_2

19. Specific Volume of cylindrical virus particle is 6.02×10^{-2} cc/g, whose radius and length are 7 Å and 10 Å respectively. If $N_A = 6.02 \times 10^{23}$. Find molecular weight of virus: *(2001)*

a. 15.4 kg/mol b. 1.54×10^4 kg/mol
c. 3.08×10^4 kg/mol d. 3.08×10^3 kg/mol

20. The number of atoms in 4.25 g of NH_3 is approximately: *(1999)*

a. 4×10^{23} b. 2×20^{23}
c. 1×10^{23} d. 6×10^{23}

21. Haemoglobin contains 0.334% of iron by weight. The molecular weight of haemoglobin is approximately 67200. The number of iron atoms (Atomic weight of Fe is 56) present in one molecule of haemoglobin is: *(1998)*

a. 4 b. 6
c. 3 d. 2

22. The number of moles of oxygen in one litre of air containing 21% oxygen by volume, under standard conditions, is: [MR*] *(1995)*

a. 0.0093 mol b. 2.10 mol
c. 0.186 mol d. 0.21 mol

23. The total number of valence electrons in 4.2 g of N_3^- ion is (N_A is the Avogadro's number): *(1994)*

a. 2.1 N_A b. 4.2 N_A
c. 1.6 N_A d. 3.2 N_A

24. The number of gram molecules of oxygen in 6.02×10^{24} CO molecules is: *(1990)*

a. 10 g molecules b. 5 g molecules
c. 1 g molecules d. 0.5 g molecules

25. Ratio of C_p and C_v of a gas '*X*' is 1.4. The number of atoms of the gas '*X*' present in 11.2 litres of it at NTP will be: *(1989)*

a. 6.02×10^{23} b. 1.2×10^{23}
c. 3.01×10^{23} d. 2.01×10^{23}

26. The number of oxygen atoms in 4.4 g of CO_2 is: *(1989)*

a. 1.2×10^{23} b. 6×10^{22}
c. 6×10^{23} d. 12×10^{23}

27. 1 c.c. N_2O at NTP contains: [MR*] *(1988)*

a. $\frac{1.8}{224} \times 10^{22}$ atoms b. $\frac{6.02}{22400} \times 10^{23}$ molecules
c. $\frac{1.32}{224} \times 10^{23}$ electrons d. All the above

28. At S.T.P., the density of CCl_4 vapour in g/L will be nearest to *(1988)*

a. 6.87 b. 3.42
c. 1026 d. 4.57

Percentage Composition, Empirical & Molecular Formula

29. An organic compound contains 78% (by wt.) carbon and remaining percentage of hydrogen. The right option for the empirical formula of this compound is: [Atomic wt. of C is 12, H is 1] *(2021)*

a. CH_2 b. CH_3
c. CH_4 d. CH

30. An organic compound contains carbon, hydrogen and oxygen. Its elemental analysis gave C-38.71% and H-9.67%. The empirical formula of the compound would be: *(2008)*

a. CH_4O b. CH_3O
c. CH_2O d. CHO

31. The percentage of C, H and N in an organic compound are 40%, 13.3% and 46.7% respectively then empirical formula is: [MR*] *(2002)*

a. $C_3H_{13}N_3$ b. CH_2N
c. CH_4N d. CH_6N

32. Percentage of Se in peroxidase anhydrous enzyme is 0.5% by weight (atomic weight = 78.4) then minimum molecular weight of peroxidase anhydrous enzymes is: *(2001)*

a. 1.568×10^4 b. 1.568×10^3
c. 15.68 d. 2.136×10^4

33. Oxidation numbers of A, B and C are +2, +5 and –2 respectively, possible formula of compound is: [MR*] *(2000)*

a. $A_2(BC_2)_2$ b. $A_3(BC_4)_2$
c. $A_2(BC_3)_2$ d. $A_3(B_2C)_2$

34. An organic compound containing C, H and N gave the following results on analysis C = 40%, H = 13.33%, N = 46.67%. Its empirical formula would be: *(1998)*

a. $C_2H_7N_2$ b. CH_5N
c. CH_4N d. C_2H_7N

Stoichiometry and Stoichiometric Calculations

35. The right option for the mass of CO_2 produced by heating 20 g of 20% pure limestone is (Atomic mass of Ca = 40)

$\left[CaCO_3 \xrightarrow{1200\,K} CaO + CO_2\right]$ *(2023)*

a. 1.32 g b. 1.12 g
c. 1.76 g d. 2.64 g

36. The number of moles of hydrogen molecules required to produce 20 moles of ammonia through Haber's process is: *(2019)*

a. 10 b. 20
c. 30 d. 40

37. A mixture of 2.3 g formic acid and 4.5 g oxalic acid is treated with concentration H_2SO_4. The evolved gaseous mixture is passed through KOH pellets. Weight (in g) of the remaining product at STP will be: [MR*] *(2018)*

a. 1.4 b. 3.0
c. 4.4 d. 2.8

38. What is the mass of the precipitate formed when 50 mL of 16.9% solution of $AgNO_3$ is mixed with 50 mL of 5.8% NaCl solution? [MR*] *(2015 Re)*
(Ag = 107.8, N = 14, O = 16, Na = 23, Cl = 35.5)

a. 3.5 g b. 7 g
c. 14 g d. 28 g

39. 20.0 g of a magnesium carbonate sample decomposes on heating to give carbon dioxide and 8.0 g magnesium oxide. What will be the percentage purity of magnesium carbonate in the sample? *(2015 Re)*
(Atomic weight of Mg = 24)

a. 96 b. 60
c. 84 d. 75

40. When 22.4 litres of $H_2(g)$ is mixed with 11.2 litres of $Cl_2(g)$, each at STP, the moles of HCl(g) formed is equal to: *(2014)*

a. 2 mol of HCl(g) b. 0.5 mol of HCl(g)
c. 1.5 mol of HCl(g) d. 1 mol of HCl(g)

41. 1.0 g of magnesium is burnt with 0.56 g O_2 in a closed vessel. Which reactant is left in excess and how much? *(2014)*
(Atomic weight Mg = 24; O = 16)

a. O_2, 0.16 g b. Mg, 0.44 g
c. O_2, 0.28 g d. Mg, 0.16 g

42. 10 g of hydrogen and 64 g of oxygen were filled in a steel vessel and exploded. Amount of water produced in this reaction will be: *(2009)*

a. 3 mol b. 4 mol
c. 1 mol d. 2 mol

43. What volume of oxygen gas (O_2) measured at 0°C and 1 atm, is needed to burn completely 1 L of propane gas (C_3H_8) measured under the same conditions? *(2008)*

a. 10 L b. 7 L
c. 6 L d. 5 L

44. How many moles of lead(II) chloride will be formed from a reaction between 6.5 g of PbO and 3.2 g HCl? *(2008)*

a. 0.011 b. 0.029
c. 0.044 d. 0.333

45. Volume of CO_2 obtained by the complete decomposition of 9.85 gm $BaCO_3$ is: *(2000)*

a. 2.24 L b. 1.12 L
c. 0.84 L d. 0.56 L

46. In the reaction

$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O\ (l)$

when 1 mole of ammonia and 1 mole of O_2 are made to react to completion then: *(1998)*

a. 1.0 mole of H_2O is produced
b. 1.0 mole of NO will be produced
c. All the oxygen will be consumed
d. All the ammonia will be consumed

47. The amount of zinc required to produce 224 mL of H_2 at STP on treatment with dilute H_2SO_4 will be: [MR*] *(1996)*

a. 65 g b. 0.065 g
c. 0.65 g d. 6.5 g

48. What is the weight of oxygen required for the complete combustion of 2.8 kg of ethylene? *(1989)*

a. 2.8 kg b. 6.4 kg
c. 9.6 kg d. 96 kg

49. A metal oxide has the formula Z_2O_3. It can be reduced by hydrogen to give free metal and water. 0.1596 g of the metal oxide requires 6 mg of hydrogen for complete reduction. The atomic weight of the metal is: *(1989)*

a. 27.9 g b. 159.6 g
c. 79.8 g d. 55.8 g

50. One litre hard water contains 12.00 mg Mg^{2+}. Milli-equivalents of washing soda required to remove its hardness is: *(1988)*

a. 1 b. 12.16
c. 1×10^{-3} d. 12.16×10^{-3}

Concentration Terms

51. The density of 1 M solution of a compound 'X' is 1.25g mL^{-1}. The **correct** option for the molality of solution is (Molar mass of compound X = 85 g): *(2023-Manipur)*

a. 0.705 m b. 1.208 m
c. 1.165 m d. 0.858 m

52. What mass of 95% pure $CaCO_3$ will be required to neutralise 50 mL of 0.5 M HCl solution according to the following reaction? [MR*] *(2022)*

$CaCO_{3(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + CO_{2(g)} + 2H_2O_{(l)}$

[Calculate upto second place of decimal point]

a. 9.50 g b. 1.25 g

c. 1.32 g d. 3.66 g

53. 6.02×10^{20} molecules of urea are present in 100 mL of its solution. The concentration of solution is: [MR*] *(2013)*

a. 0.02 M b. 0.01 M

c. 0.001 M d. 0.1 M

54. An excess of $AgNO_3$ is added to 100 mL of a 0.01 M solution of dichlorotetraaquachromium(III) chloride. The number of moles of AgCl precipitated would be: [MR*] *(2013)*

a. 0.001 b. 0.002

c. 0.003 d. 0.01

55. How many grams of concentrated nitric acid solution should be used to prepare 250 mL of 2.0 M HNO_3? The concentrated acid is 70 % HNO_3: *(2013)*

a. 45.0 g conc. HNO_3 b. 90.0 g conc. HNO_3

c. 70.0 g conc. HNO_3 d. 54.0 g conc. HNO_3

56. 25.3 g of sodium carbonate, Na_2CO_3 is dissolved in enough water to make 250 mL of solution. If sodium carbonate dissociates completely, molar concentration of sodium ion, Na^+ and carbonate ions, CO_3^{2-} are respectively:

(Molar mass of Na_2CO_3 = 106 g mol^{-1}) *(2010 Pre)*

a. 0.477 M and 0.477 M b. 0.955 M and 1.910 M

c. 1.910 M and 0.955 M d. 1.90 M and 1.910 M

57. The mole fraction of the solute in one molal aqueous solution is: *(2005)*

a. 0.054 b. 0.042

c. 0.018 d. 0.009

58. Find the molarity of liquid HCl if density of liq. HCl is 1.17 g/cc: *(2001)*

a. 36.5 b. 18.25

c. 32.05 d. 42.10

59. How many gram of dibasic acid (molecular wt. 200) should be present in 100 ml of the aqueous solution to give 0.1 N? *(1999)*

a. 1g b. 2g

c. 10g d. 20g

60. A 5 molar solution of H_2SO_4 is diluted from 1 litre to a volume of 10 litres, the normality of the solution will be: [MR*] *(1991)*

a. 1 N b. 0.1 N

c. 5 N d. 0.5 N

Answer Key

1. (c)	**2.** (c)	**3.** (d)	**4.** (c)	**5.** (c)	**6.** (d)	**7.** (b)	**8.** (a)	**9.** (c)	**10.** (c)
11. (a)	**12.** (d)	**13.** (a)	**14.** (c)	**15.** (a)	**16.** (c)	**17.** (d)	**18.** (b)	**19.** (a)	**20.** (d)
21. (a)	**22.** (a)	**23.** (c)	**24.** (b)	**25.** (a)	**26.** (a)	**27.** (d)	**28.** (a)	**29.** (b)	**30.** (b)
31. (c)	**32.** (a)	**33.** (b)	**34.** (c)	**35.** (c)	**36.** (c)	**37.** (d)	**38.** (b)	**39.** (c)	**40.** (d)
41. (d)	**42.** (b)	**43.** (d)	**44.** (b)	**45.** (b)	**46.** (c)	**47.** (c)	**48.** (c)	**49.** (d)	**50.** (a)
51. (d)	**52.** (c)	**53.** (b)	**54.** (a)	**55.** (a)	**56.** (c)	**57.** (c)	**58.** (c)	**59.** (a)	**60.** (a)

Explanations

1. (c) The final result in case of multiplication and division, should be reported as having the same number of significant figures as the number with least number of significant figures.

$$\text{As, Density} = \frac{\text{Mass}}{\text{Volume}}$$

Therefore, mass = density × volume

$= 2.15 \times 2.5$

$= 5.375$

$= 5.4$ g

2. (c) According to Avogadro's principle, ratio of volume of gases will be equal to the ratio of their number of moles.

Molar masses of H_2, O_2 and CH_4 are 2, 32 and 16 respectively.

$$\text{mole} = \frac{w}{M_w}$$

$$n_{H_2} : n_{O_2} : n_{CH_4}$$

$$\frac{w}{2} : \frac{w}{32} : \frac{w}{16} \Rightarrow 16 : 1 : 2$$

3. (d) (i) All non-zero digit are significant.

(ii) Non-zero digit to the right of the decimal point are significant.

(iii) Zeros to the left of the first non-zero digit number are not significant.

So, the number of significant figures for the number 161 cm, 0.161 cm and 0.0161 cm are same, i.e., 3.

4. (c) Avogadro law states that equal volumes of all gases at the same temperature and pressure contain equal number of molecules. If 1 L of one gas contains N molecules, 2 L of any gas under the same conditions will contain 2 N molecules.

5. (c) Let x and y be the atomic weights of X and Y, respectively.
Given: 0.1 mole of XY_2 weighs 10g
$\Rightarrow x + 2y = 10/0.1 = 100$ ...(i)
0.05 mole of X_3Y_2 weighs 9g.
$\Rightarrow 3x + 2y = 9/0.05 = 180$ ...(ii)
From equation (i), we get
$x = 100 - 2y$
Substituting x in equation (ii), we get
$3(100 - 2y) + 2y = 180$
$300 - 6y + 2y = 180$
$\Rightarrow y = 30$
As a result, $x = 100 - 2(30) = 40$

6. (d) The formula to calculate average atomic mass is:

$$W_{Avg} = \frac{w_1x_1 + w_2x_2 + w_3x_3}{x_1 + x_2 + x_3}$$

w = isotopic weight
x → percentage of isotope

$$W_{Avg} = \frac{(200\times90)+(199\times8)+(202\times2)}{(90+8+2)}$$

$W_{Avg} = 200$ amu

7. (b) Weight of gas = 0.24 g. Volume of gas = 45 mL = 0.045 litre and density of $H_2 = 0.089$.

We know that weight of 45 mL of H_2 = Density × Volume $= 0.089 \times 0.045 = 4.005 \times 10^{-3}$ g.

Therefore,

$$\text{Vapour density} = \frac{\text{weight of certain volume of substance}}{\text{weight of same volume of hydrogen}}$$

$$= \frac{0.24}{4.005\times10^{-3}} = 59.93$$

8. (a) The formula to calculate average atomic weight is:

Average Atomic Weight = (Atomic number of isotope 1 × its percentage + atomic number of isotope 2 × its percentage)/100.

$$\text{Average atomic weight} = \frac{10\times19+11\times81}{100}$$

$$= 10.81$$

9. (c) 1 mol of any substance contains Avogadro number of atoms.
Also, Mole = Weight/Molar Mass
(a) Number of Mg atoms = Moles of Mg × N_A

$$= \frac{1}{24}\times N_A$$

$$= \frac{1}{24}\times6.022\times10^{23} \text{ atom}$$

(b) Number of O atoms = Moles of O_2 × N_A

$$= \frac{1}{32}\times N_A$$

$$= \frac{1}{32}\times2\times6.022\times10^{23} \text{ atom}$$

(c) Number of Li atoms = Moles of Li × N_A

$$= \frac{1}{7}\times N_A$$

$$= \frac{1}{7}\times6.022\times10^{23} \text{ atom}$$

(d) Number of Ag atoms = Moles of Ag × N_A

$$= \frac{1}{108}\times N_A$$

$$= \frac{1}{108}\times6.022\times10^{23} \text{ atom}$$

Hence, 1g lithium has the largest number of atoms.

10. (c) As we know, 1 mole of carbon weighs 12 g
Also, 1 mol contains 6.022×10^{23} atoms
Thus, Number of atoms in 1 mole carbon = 6.022×10^{23} atoms

11. (a) Molar mass of water = 18g/mol
Moles = Given weight/Molar Mass
(a) Density = Mass/Volume
Also, Density of water = 1g/mL
Hence, Mass of water = 18 × 1 = 18 g
Molecules of water = mole × $N_A = \frac{18}{18}N_A = 1\ N_A$

(b) Molecules of water = mole × $N_A = \frac{0.18}{18}N_A = 10^{-2}\ N_A$

(c) Molecules of water = mole × $N_A = 10^{-3}N_A$
(d) 22.4 L of water = 1 mol of water
Hence, 0.00224 L of water = 0.00224/22.4 = 10^{-4} moles
Molecules of water = mole × $N_A = 10^{-4}\ N_A$

12. (d) Number of moles of H_2 = Weight of H_2/Molar Mass = 1/2
Number of moles of O_2 = Weight of O_2/Molar Mass = $\frac{4}{32}$
Hence, molar ratio = $\frac{1}{2}:\frac{4}{32} = 4:1$

13. (a) we know that,
1 mole of any substance contains Avogadro number of molecules
(a) 18 moles of water will contain = $18 \times 6.022 \times 10^{23}$ molecules of H_2O
(b) 18 molecules
(c) Number of moles of water = Weight/Molar Mass $= \frac{1.8}{18} = 0.1$ mole
Hence, number of molecules in 0.1 mole of water $= 0.1 \times 6.022 \times 10^{23}$ molecules
(d) Number of moles of water = given weight/molar mass $= \frac{18}{18}g = 1\text{mole}$
Hence, number of molecules in 1 mole of water = $1 \times 6.22 \times 10^{23}$ molecules.
So, maximum number of molecules is present in 18 moles of H_2O.

14. (c) Avogadro's number 6.022×10^{23} is ideally the mass of number of atoms present in 1 mole that is 12 grams of C. If we change the Avogadro's number, it will directly change the mass of 1 mole that is 12 g of C.

15. (a) 64 g of SO_2 = 1 mole = N_A number of molecules
8 g of H_2 = 4 moles = 4 × N_A number of molecules
48 g of O_3 = 1 mole = N_A number of molecules
44 g of CO_2 = 1 mole = N_A number of molecules
So, 8 g of H_2 has maximum number of molecules.

16. **(c)** For triatomic gas, number of atoms per molecule = 3
Hence, number of atoms in its 0.1 mole = $3 \times 0.1 \times 6.022 \times 10^{23} = 1.806 \times 10^{23}$

17. **(d)** At S.T.P, 22.4 L of $H_2 = 6.022 \times 10^{23}$ molecules

$$15\ L(H_2) = \frac{6.022 \times 10^{23} \times 15}{22.4} = 4.033 \times 10^{23} \text{ molecules}$$

$$5\ L(N_2) = \frac{6.022 \times 10^{23} \times 5}{22.4} = 1.34 \times 10^{23} \text{ molecules}$$

$2\ g\ H_2 = 6.022 \times 10^{23}$ molecules

$$\text{So, } 0.5\ g(H_2) = \frac{6.022 \times 10^{23} \times 0.5}{2} = 1.505 \times 10^{23} \text{ molecules}$$

$32g\ O_2 = 6.022 \times 10^{23}$ molecules

$$\text{So, } 10\ g(O_2) = \frac{6.022 \times 10^{2} \times 10}{32} = 1.88 \times 10^{23} \text{ molecules}$$

18. **(b)** 1 mole = 6.022×10^{23} molecules

$$7g\ N_2 \text{ has} = \frac{7g}{28g\ mol^{-1}} = 0.5 \text{ mole}$$

Hence, 0.5 mole of N_2 has $0.5 \times 6.022 \times 10^{23}$ molecules

$$2g\ H_2 = \frac{2g}{2g\ mol^{-1}} = 1 \text{ mole}$$

Hence, 1 mole of H_2 has 6.022×10^{23} molecules

$$16g\ NO_2 = \frac{16g}{46g\ mol^{-1}} = 0.348 \text{ mole}$$

Hence, 0.348 mole H_2 has $0.348 \times 6.022 \times 10^{23}$ molecules

$$16g\ O_2 = \frac{16g}{32g\ mol^{-1}} = 0.55 \text{ mole}$$

Hence, 0.55 mole has $0.55 \times 6.022 \times 10^{23}$ molecules

19. **(a)** Volume of one cylindrical virus = $\pi r^2 h$

$$= \frac{22}{7} \times 7 \times 7 \times 10 Å^3 = 22 \times 7 \times 10^{-30}\ m^3 = 1.54 \times 10^{-27}\ m^3$$

So, volume of one mole of virus = $6.023 \times 10^{23} \times$ vol. of one virus
$= 6.023 \times 10^{23} \times 1.54 \times 1^{-27}\ m^3$
$= 9.275 \times 10^{-4}\ m^3$ or $9.275 \times 10^{2}\ cm^3$ (1m = 100 cm) Molecular wt. $= \frac{\text{vol. of 1 mole}}{\text{specific volume}}$

$$= \frac{9.275 \times 10^{2}\ cm^3 mol^{-1}}{6.02 \times 10^{-2}\ cm^3 g^{-1}}$$

$= 15406.9\ g\ mol^{-1}$

20. **(d)** 1 mole of NH_3 contains $4 \times N_A$ atoms i.e. $4 \times 6.022 \times 10^{23}$

$$\text{No. of moles present in 4.25 g of } NH_3 = \frac{4.25g}{17g\ mol^{-1}}$$

$= 0.25$ mol

Hence 0.25 mol will contain $(0.25 \times 4 \times 6.022 \times 10^{23})$ i.e., 6.022×10^{23} no. of atoms

21. **(a)** Weight of iron in one molecule of

$$\text{Haemoglobin} = \text{Percent of iron by weight} \times 67200 \times \frac{0.334}{100}$$

$= 224.45$ amu

$$\text{Number of iron atom} = \text{Molar mass of Fe} = \frac{224.45}{56} = 4$$

22. **(a)** Volume of oxygen in one litre of air

$$= \frac{21}{100} \times 1000 = 210\ mL$$

Number of moles occupied by 22400 mL of gas at STP = 1 mol
Number of moles occupied by 210 mL of gas

$$= \frac{210}{22400} = 0.0093 \text{ mol}$$

23. **(c)** Each nitrogen atom has 5 valence electrons, and also, since there is negative charge on it, so there will be one more extra electron, therefore total number of electrons in N_3^- ion is 16. Since the molecular mass of N_3^- is 42, therefore total number of electrons in 4.2 g of N_3^- ion

$$= \frac{4.2}{42} \times 16 \times N_A = 1.6 N_A$$

24. **(b)** No. of oxygen atoms = No. of CO molecules = 6.022×10^{24}

$$\text{No. of oxygen molecule} = \frac{1}{2} \times \text{No. of oxygen atoms}$$

$$= \frac{1}{2} \times 6.022 \times 10^{24} = 3.011 \times 10^{24}$$

$$\text{No. of gram molecule of } O_2 \text{ molecules} = \frac{3.022 \times 10^{24}}{6.022 \times 10^{23}} = 5 \text{ g molecules}$$

25. **(a)** Here, $C_p/C_v = 1.4$ which shows that the gas is diatomic.
22.4 L at NTP = 6.02×10^{23} molecules
$\therefore$ 11.2 L at NTP = 3.01×10^{23} atoms
Since gas is diatomic.
$\therefore$ 11.2 L at NTP = $2 \times 3.01 \times 10^{23} = 6.02 \times 10^{23}$ atom

26. **(a)** 1 mol of CO_2 = 44 g of CO_2
$\therefore$ 4.4 g CO_2 = 0.1 mol CO_2
$= 6 \times 10^{22}$ molecules
[since, 1 mole $CO_2 = 6 \times 10^{23}$ molecules]
Number of O-atoms in 4.4g $CO_2 = 2 \times 6 \times 10^{22}$ atoms of O
$= 1.2 \times 10^{23}$ atoms of O

27. **(d)** As we know,
22400 cc of N_2O contain 6.02×10^{23} molecules
$\therefore$ 1 cc of N_2O contain $\frac{6.02 \times 10^{23}}{22400}$ molecules
Since in N_2O molecule there are 3 atoms.

$$\therefore \text{ 1 cc } N_2O = \frac{3 \times 6.02 \times 10^{23}}{22400} \text{ atoms.}$$

$$= \frac{1.8 \times 10^{22}}{224} \text{ atoms}$$

No. of electrons in a molecule of $N_2O = 7 + 7 + 8 = 22$
[Z of N = 7 and O = 8]

$$\text{Hence, no. of electrons} = \frac{6.02 \times 10^{23}}{22400} \times 22 \text{ electrons}$$

$$= \frac{1.32}{224} \times 10^{23} \text{ electron}$$

28. **(a)** At STP, V = 22.4 L
M = 154 g

$$\therefore \text{ Density of } CCl_4 \text{ vapour} = \text{Mass/Volume} = \frac{154}{22.4}\ gL^{-1}$$

$= 6.875\ gL^{-1}$

29. (b) Given organic compound contains carbon = 78 % (by wt.)
Therefore, given organic compound contains nitrogen = (100 – 78)% = 22 %

Now,

Element	Mass percentage	No. of moles = Given weight/ Molar mass	Mole ratio
C	78%	$\frac{78}{12}=6.5$	$\frac{6.5}{6.5}=1$
H	22%	$\frac{22}{1}=22$	$\frac{22}{6.5}=2.38\simeq 3$

Hence, empirical formula of the given compound is CH_3.

30. (b) As per empirical formula concept:

Element	%	Molar Ratio	Converting to simple Ratio
C	38.71	3.22	3 → 1
H	9.67	9.67	9 → 3
O	51.62	3.22	3 → 1

Formula becomes: CH_3O

31. (c)

Element	%	At	Relative number	Ratio
C	40.00	12	40/12=3.66	366/3.66 = 1.09 = 1
H	13.33	1	13.33/1 = 13.33	13.33/3.33 = 4
N	46.67	14	46.67/14 = 3.33	3.33/3.33 = 1

Hence, empirical formula is CH_4N

32. (a) 0.5% Se means 0.5g of Selenium in 100g of enzyme.
According to Question,
0.5 g selenium is present in 100g enzyme
Hence, 78.4 g of Selenium will be present in (100/78.4) × 0.5 = 1.568×10^4.

33. (b) In $A_3(BC_4)_2$: (+2) × 3 + 2 [+ 5 + 4(–2)]
⇒ +6 +10 – 16 = 0
Hence in the compound $A_3(BC_4)_2$, the oxidation number of 'A', 'B' and 'C' are +2, +5 and –2 respectively.

34. (c)

Element	%	At	Relative number	Ratio
C	40.00	12	40/12=3.66	366/3.66 = 1.09 = 1
H	13.33	1	13.33/1 = 13.33	13.33/3.33 = 4
N	46.67	14	46.67/14 = 3.33	3.33/3.33 = 1

Hence, empirical formula is CH_4N

35. (c) 20 g of 20% $CaCO_3 = 20\times\frac{20}{100} = 4$g $CaCO_3$

$$\underset{100g}{CaCO_3} \xrightarrow{1200K} CaO + \underset{44g}{CO_2}$$

According to the reaction,
100g of $CaCO_3 \rightarrow$ 44g of CO_2

4g $CaCO_3 \rightarrow \frac{4\times44}{100}$ g of CO_2

= 1.76 g of CO_2

36. (c) According to Haber's process

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

2 moles of $NH_3 \rightarrow$ 3 moles of H_2

Hence, 20 moles of $NH_3 \rightarrow \frac{3\times20}{2}$ = 30 moles to H_2

37. (d) Moles = Weight /Molar Mass
Molar mass of HCOOH = 46
Molar mass of HOOC – COOH
The following equations can be obtained from the given data:

$$HCOOH \xrightarrow[KOH\ pellets]{H_2SO_4} CO + H_2O$$

$$HOOC - COOH \xrightarrow[KOH\ pellets]{H_2SO_4} CO + CO_2 + H_2O$$

Moles of formic acid, HCOOH = 2.3/46 = 0.05 moles
Moles of HOOC – COOH = 4.5/90 = 0.05 moles
From reaction 1), We know that the number of moles of CO formed is 0.05 mole
From reaction 2), Number of moles of CO formed is 0.05 mole
Therefore, total number of moles of CO formed is 0.05 mol + 0.05 mol = 0.1 mol
And, total number of moles of CO_2 formed is 0.05 mole
As, we know that KOH pellets absorb all CO_2, and H_2O is absorbed by H_2SO_4.
Therefore, CO is the remaining product.
Hence, the weight of the remaining product = 0.1 × 28 = 2.8g

38. (b) Molecular weight of $AgNO_3$ = 170
Molecular weight of NaCl = 58.5

1. 16.9% solution of $AgNO_3$ means 16.9 g of $AgNO_3$ in 100 mL of solution
Hence, 8.45 g of $AgNO_3$ in 50 mL of solution.
2. 5.8% solution of NaCl means 5.8 g of NaCl is in 100 mL solution. So, in 50 mL, there will be = 2.9 g NaCl

$$AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$$

Initial Mole: $\frac{8.45}{170}$ $\frac{2.9}{58.5}$ 0 0

= 0.049 = 0.049 0 0

Final mole: 0 0 0.049 0.049

Mass of AgCl precipitated = Moles of AgCl × Molar Mass of AgCl
Mass of AgCl precipitated = 0.049 × 143.3 = 7.02 gm = 7 gm
(Molar mass of AgCl = 143.3 g/mol)

39. (c)

$$MgCO_3 \rightarrow \underset{\downarrow}{MgO} + \underset{\downarrow 44}{CO_2(g)}$$

$M_w \rightarrow$ 84 g 40 g

According to question:
84 g $MgCO_3$ gives = 40 g MgO
1 g $MgCO_3$ gives = $\frac{40}{84}$ g MgO
20 g $MgCO_3$ gives = $\frac{40}{84}\times20$ g MgO
= 9.52 g of MgO

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But according to question
yield of MgO is = 8 g
Hence, % purity = Mass of pure compound/Total mass of impure sample $\times 100 = \frac{8}{9.52} \times 100 = 84\%$

40. (d) 1 mole = 22.4 litres at S.T.P.
(Given weight/molar mass) =
$n_{H_2} = \frac{22.4}{22.4} = 1 \text{ mol}$; $n_{Cl_2} = \frac{11.2}{22.4} = 0.5 \text{ mol}$
Reaction is as,

	$H_2(g)$	+ $Cl_2(g)$	→ $2HCl(g)$
Initial	1 mol	0.5 mol	0
Final	(1 – 0.5) = 0.5 mol	(0.5 – 0.5) = 0 mol	2 × 0.5 = 1 mol

Here, Cl_2 is limiting reagent.
According to the equation,
1 mol of $Cl_2 \rightarrow$ 2 mol of HCl
0.5 mol of $Cl_2 \rightarrow (2 \times 0.5)/1$ mol of HCl
Hence, 1 mol of HCl is formed.

41. (d) (Given weight/ molar mass) = $n_{Mg} = \frac{1}{24} = 0.0416$ moles

$n_{O_2} = \frac{0.56}{32} = 0.0175$ moles

The balanced chemical equation:

	Mg +	$\frac{1}{2}O_2$ →	MgO
Initial	0.0416 moles	0.0175 moles	0
Final	(0.0416 – 2 × 0.0175) = 0.0066 moles	0	2 × 0.0175

Hence, O_2 is limiting reagent.
∴ Mass of Mg left in excess = 0.0066 × 24
= 0.16 g
(Moles of Mg left after reaction × Molar mass of Mg)

42. (b)

H_2 +	$\frac{1}{2}O_2$ →	H_2O
2 g	16 g	18 g
1 mol	0.5	1 mol

10 g of H_2 = 5 mol; 64 g of O_2 = 2 mol
According to the reaction,
0.5 mole of oxygen requires 1 mol of hydrogen gas
So, 2 mol of oxygen will require $(2 \times 1)/0.5 = 4$ mol of Hydrogen
∴ In this reaction, oxygen is the limiting reagent so, amount of H_2O produced depends on the O_2.
Since 0.5 mol of O_2 gives 1 mol H_2O
∴ 2 mol of O_2 will give 4 mol H_2O.

43. (d) According to the chemical equation:
$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$
At STP, 22.4 L of $C_3H_8(g)$ is present
At STP, 5 × 22.4 L of $O_2(g)$ is present
According to stoichiometric rule:
1 L of $C_3H_8(g)$ at STP $= \frac{5 \times 22.4}{22.4} = 5$ L of $O_2(g)$ at STP

44. (b)

	PbO +	$2HCl \rightarrow PbCl_2 + H_2O$	
given mole	$\frac{6.5}{224}$	$\frac{3.2}{36.5}$	
	= 0.029 mole,	0.087 mole	

According to the reaction,
1 mol of PbO requires 2 moles of HCl
Hence, 0.029 mol of PbO will require 0.058 moles of HCl
Thus HCl is present in excess and PbO is a limiting reagent.
According to reaction:
1 mole of PbO gives = 1 mole $PbCl_2$
So, 0.029 mole of PbO gives = 0.029 mole of $PbCl_2$

45. (b) The decomposition reaction of $BaCO_3$ can be written as:
$BaCO_3 \rightarrow BaO + CO_2$
According to the reactions
197.34 g of $BaCO_3 \rightarrow$ 22.4 L of CO_2 at N.T.P.
9.85 g of $BaCO_3 \rightarrow (22.4/197.34) \times 9.85 = 1.118$ L of CO_2 at
9.85 g $BaCO_3$
Hence, will produce 1.118 L CO_2 at N.T.P on the complete decomposition.

46. (c) $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(l)$
4 mol + 5 mol → 4 mol + 6 mol
According to equation
5mole of O_2 requires = 4 moles of NH_3
Therefore,
1 mole of O_2 required = 4/5 i.e. 0.8 mole of NH_3
Similarly, we can say
4 moles of NH_3 requires = 5 moles of O_2
Hence, 1 mole of NH_3 requires 5/4 i.e. 1.25 moles of O_2
As there is 1 mole of NH_3 and 1 mole of O_2. So, all oxygen will be consumed.

47. (c) $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$
(65 g)
According to the equation,
65g of Zn produces 1 mol of H_2.
Also, At STP,
1 mol of H_2 occupies 22400 mL of H_2.
Now, Amount of Zinc required to liberate 22400 mL of Hydrogen at STP = 65 g
Hence, the amount of zinc needed to produce 224 mL of H_2 at STP = 65/22400 × 224 = 0.65 g

48. (c) $C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$
28 kg 96 kg
Since the weight of oxygen required for the complete combustion of 28 kg ethylene = 96 kg
Therefore, the weight of oxygen required for the combustion of 2.8 kg ethylene = (96 × 2.8 /28) = 9.6 kg

49. **(d)** $Z_2O_3 + 3H_2 \rightarrow 2Z + 3H_2O$

0.1596 g of metal oxide requires 6 mg i.e. 6×10^{-3} g H_2

x g of metal oxide will require 6g of H_2

$\therefore$ Weight of Z_2O_3 i.e. $x = \frac{6 \times 0.1596}{6 \times 10^{-3}} = 156.69g$

Weight of 2Z = weight of Z_2O_3 – wt. of O_2

= 159.6 – 48 = 111.6 g

Atomic wt. of $z = \frac{111.6}{2} g = 55.8g$

50. **(a)** $Mg^{2+} + Na_2CO_3 \rightarrow MgCO_3 + 2Na^+$

1 g eq. 1 g eq.

1 g eq. of Mg^{2+} = 12 g of Mg^{2+} = 12000 mg

Now, 1000 millieq. of Na_2CO_3 = 12000 mg of Mg^{2+}

$\therefore$ 1 millieq. of Na_2CO_3 = 12 mg of Mg^{2+}

51. **(d)** The relation between M and *m* is:

$$m = \frac{1000 \times M}{1000 \times d - MM_w}$$

$$m = \frac{1000 \times 1}{1000 \times 1.25 - 1 \times 85}$$

$$m = \frac{1000}{1165} = 0.858 \text{ m}$$

52. **(c)** $CaCO_{3(s)} + 2HCl_{(aq.)} \rightarrow CaCl_{2(aq.)} + CO_{2(g)} + H_2O_{(l)}$

no. of moles of $CaCO_3$ (pure) $= \frac{1}{2} \times$ mole of HCl

[No. of Moles = molarity × volume of solution (in ltr.)]

$= \frac{1}{2} \times 0.5 \times \frac{50}{1000} = 0.0125$

weight of $CaCO_3$ (pure) = mole × mol. wt

= 0.0125 × 100 = 1.25 g

$$\%\text{purity} = \frac{\text{wt. of pure substance}}{\text{wt. of impure sample}} \times 100$$

wt. of impure sample $= \frac{1.25 \times 100}{95} = 1.32g$

53. **(b)** 6.02×10^{23} number of molecules = 1 mole

6.02×10^{20} number of molecules = 0.001 mole

Concentration $= \frac{\text{mole}}{V(mL)} \times 1000 = \frac{0.001}{100} \times 1000 \Rightarrow 0.01$ M

54. **(a)** The reaction takes place as:

$$[Cr(H_2O)_4(Cl)_2]Cl \xrightarrow{\text{excess } AgNO_3} [Cr(H_2O)_4(Cl)_2]^+ + AgCl\downarrow$$

$$\text{Molarity} = \frac{\text{Number of moles}}{\text{Volume}} \times 1000$$

On substituting values, $0.01 = \frac{\text{Number of moles}}{100} \times 1000$

Hence, the number of moles of AgCl = 0.001

55. **(a)** Molarity is defined as the number of moles of solute per litre of solution.

Hence, volume = 1L = 1000 mL

Moles of HNO_3 = M × V = (2 × 250)/1000 = 0.5 moles

The mass of nitric acid can be obtained by multiplying the number of moles by molar mass and dividing by percentage concentration.

Therefore, HNO_3 required $= 0.5 \times 63 \times \frac{100}{70} = 45g$

56. **(c)** Given Volume = 250 mL,

Hence V(in L) = 250/1000 = 0.25L

Number of moles of Na_2CO_3 = Weight/Molar Mass

= 25.3/106 = 0.239 moles

(Molar mass of Na_2CO_3 = 106 g/mol)

Molarity of solution = Number of moles/Volume (in L)

= 0.239/0.25 = 0.956 mol/litre

$Na_2CO_3 \rightarrow 2Na^+ + CO_3^{2-}$

According to the above equation,

Concentration of CO_3^{2-} = Concentration of Na_2CO_3 = 0.956M

Concentration of Na^+ = 2 × Concentration of Na_2CO_3

= 2 × 0.956 = 1.912 M

57. **(c)** 1 molal of aqueous solution means 1 mole of solute per 1 kg solvent

Hence, no. of moles of solvent (water) $(X_A) = \frac{1000}{18g\,mol^{-1}}$

= 55.5 mol

No. of moles of solute (X_B) = 1

Hence mole fraction of solute $= \frac{X_B}{X_A + X_B} = \frac{1}{55.5+1} = 0.018$

58. **(c)** Density = 1.17 g/cc

1 cc solution contain 1.17 g of HCl

Volume = 1 c.c = 1 mL = (1/1000)L

mol. wt. of HCl = 36.5 g mol^{-1}

Number of moles of HCl = Weight of HCl/Molar Mass of HCl = 1.17/36.5

$\therefore$ Molarity = number of moles/Volume (in L)

$= \frac{1.17 \times 1000}{36.5 \times 1} = 32.05$ M

59. **(a)** Equivalent weight of dibasic acid $= \frac{\text{Molecular wt.}}{2}$

$\Rightarrow \frac{200}{2} = 100$

$m = \frac{\text{Equivalent wt.} \times \text{Volume} \times \text{Normality}}{1000} = \frac{100 \times 100 \times 0.1}{1000}$

m = 1 g

60. **(a)** From the law of equivalence:

$N_1V_1 = N_2V_2$

or $n_f \times M_1V_1 = n_f M_2V_2$

$2 \times 5 \times 1 = 2 \times M_2 \times 10$ $\{n_f = 2$ for $H_2SO_4\}$

$M_2 = 0.5$ M

i.e., molarity after dilution = 0.5 M,

$\therefore$ Normality after dilution will be 1 N

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CHAPTER 2

Structure of Atom

Subatomic Particles, Atomic Models

1. Select the correct statements from the following: *(2023)*

A. Atoms of all elements are composed of two fundamental particles.

B. The mass of the electron is 9.10939×10^{-31} kg.

C. All the isotopes of a given element show same chemical properties.

D. Protons and electrons are collectively known as nucleons.

E. Dalton's atomic theory, regarded the atom as an ultimate particle of matter.

Choose the correct answer from the options given below:

a. B, C and E only
b. A, B and C only
c. C, D and E only
d. A and E only

2. The number of protons, neutrons and electrons in $^{175}_{71}Lu$, respectively, are: *(2020)*

a. 104, 71 and 71
b. 71, 71 and 104
c. 175, 104 and 71
d. 71, 104 and 71

3. Isoelectronic species are: [MR*] *(2000)*

a. CO, CN^-, NO^+, C_2^{2-}
b. CO^-, CN, NO, C_2^-
c. CO^+, CN^+, NO^-, C_2
d. CO, CN, NO, C_2

4. The ion that is isoelectronic with CO is: *(1997)*

a. CN^-
b. N_2^+
c. O^{2-}
d. N_2^-

5. Which one of the following is not isoelectronic with O^{2-}? *(1994)*

a. Tl^+
b. Na^+
c. N^{3-}
d. F^-

Developments Leading to Bohr's Model of Atom

6. When electromagnetic radiation of wavelength 300 nm falls on the surface of a metal, electrons are emitted with the kinetic energy of 1.68×10^5 J mol^{-1}. What is the minimum energy needed to remove an electron from the metal? *(2022 Re)*

($h = 6.626 \times 10^{-34}$ Js, $c = 3 \times 10^8$ ms^{-1}, $N_A = 6.022 \times 10^{23}$ mol^{-1})

a. 2.31×10^5 J mol^{-1}
b. 2.31×10^6 J mol^{-1}
c. 3.84×10^4 J mol^{-1}
d. 3.84×10^{-19} J mol^{-1}

7. A particular station of All India Radio, New Delhi, broadcasts on a frequency of 1,368 kHz (kilohertz). The wavelength of the electromagnetic radiation emitted by the transmitter is: [speed of light, $c = 3.0 \times 10^8$ ms^{-1}] *(2021)*

a. 219.2 m
b. 2192 m
c. 21.92 cm
d. 219.3 m

8. Which of the following series of transitions in the spectrum of hydrogen atom fall in visible region? *(2019)*

a. Lyman series
b. Balmer series
c. Paschen series
d. Brackett series

9. Calculate the energy in joule corresponding to light of wavelength 45 nm (Planck's constant h = 6.63×10^{-34} Js; speed of light $c = 3 \times 10^8$ ms^{-1}) [MR*] *(2014)*

a. 6.67×10^{11}
b. 4.42×10^{-15}
c. 4.42×10^{-18}
d. 6.67×10^{15}

10. The value of Planck's constant is 6.63×10^{-34} Js. The speed of light is 3×10^8 ms^{-1}. Which value is closest to the wavelength in nanometer of a quantum of light with frequency of 6×10^{15} s^{-1}? *(2013)*

a. 10 nm
b. 25 nm
c. 50 nm
d. 75 nm

11. The energies E_1 and E_2 of two radiations are 25 eV and 50 eV respectively. The relation between their wavelengths i.e., λ_1 and λ_2 will be: *(2011 Pre)*

a. $\lambda_1 = \frac{1}{2}\lambda_2$
b. $\lambda_1 = \lambda_2$
c. $\lambda_1 = 2\lambda_2$
d. $\lambda_1 = 4\lambda_2$

12. The value of Planck's constant is 6.63×10^{-34} Js. The velocity of light is 3.0×10^8 ms^{-1}. Which value is closest to the wavelength in metres of a quantum of light with frequency of 8×10^{15} s^{-1}? *(2003)*

a. 2×10^{-25}
b. 5×10^{-18}
c. 3.75×10^{-8}
d. 3×10^7

13. E = 3.03×10^{-19} Joules

For given energy, corresponding wavelength will be ($h = 6.6 \times 10^{-34}$ J sec, $c = 3 \times 10^8$ m/sec)? *(2000)*

a. 65.3 nm
b. 6.53 nm
c. 3.4 nm
d. 653 nm

14. What will be the longest wavelength line in Balmer series of spectrum? [MR*] *(1996)*

a. 546 nm
b. 656 nm
c. 566 nm
d. 556 nm

Bohr's Model For Hydrogen Atom

15. If radius of second Bohr orbit of the He^+ ion is 105.8 pm, what is the radius of third Bohr orbit of Li^{2+} ion? [MR*] *(2022)*

a. 158.7 Å
b. 158.7 pm
c. 15.87 pm
d. 1.587 pm

16. Based on equation, $E = -2.178\times10^{-18} J\left(\frac{Z^2}{n^2}\right)$ certain conclusions are written. Which of them is not correct? *(2013)*

a. The negative sign in equation simply means that the energy of electron bound to the nucleus is lower than it would be if the electrons were at the infinite distance from the nucleus.
b. Larger the value of n, the larger is the orbit radius.
c. Equation can be used to calculate the change in energy when the electron changes orbit.
d. For $n = 1$, the electron has a more negative energy than it does for $n = 6$ which means that the electron is more loosely bound in the smallest allowed orbit.

17. According to the Bohr theory, which of the following transitions in the hydrogen atom will give rise to the least energetic photon? *(2011 Pre)*

a. n = 6 to n = 5
b. n = 5 to n = 3
c. n = 6 to n = 1
d. n = 5 to n = 4

18. The energy of second Bohr orbit of the hydrogen atom is –328 kJ mol^{-1}; hence the energy of fourth Bohr orbit would be: [MR*] *(2005)*

a. –41 kJ mol^{-1}
b. –1224 kJ mol^{-1}
c. –284 kJ mol^{-1}
d. –82 kJ mol^{-1}

19. The frequency of radiation emitted when the electron falls from n = 4 to n = 1 in a hydrogen atom will be (Given ionisation energy of H = 2.18×10^{-18} J $atom^{-1}$ and h = 6.625×10^{-34} Js): *(2004)*

a. 1.03×10^{15} s^{-1}
b. 3.08×10^{15} s^{-1}
c. 2.00×10^{15} s^{-1}
d. 1.54×10^{15} s^{-1}

20. In hydrogen atom, energy of first excited state is – 3.4 eV. Then find out K.E of same orbit of hydrogen atom: *(2002)*

a. +3.4 eV
b. +6.8 eV
c. –13.6 eV
d. +13.6 eV

21. Who modified Bohr's theory by introducing elliptical orbits for electron path? *(1999)*

a. Hund
b. Thomson
c. Rutherford
d. Sommerfeld

22. Bohr's radius for the hydrogen atom (n = 1) is approximately 0.530 Å. The radius for the first excited state (n = 2) orbit is (in Å): *(1998)*

a. 0.13
b. 1.06
c. 4.77
d. 2.12

23. In a Bohr's model of an atom, when an electron jumps from $n = 1$ to $n = 3$, how much energy will be emitted or absorbed? *(1996)*

a. 2.389×10^{-12} ergs
b. 0.239×10^{-10} ergs
c. 2.15×10^{-11} ergs
d. 0.1936×10^{-10} ergs

24. The radius of hydrogen atom in the ground state is 0.53 Å. The radius of Li^{2+} ion (atomic number = 3) in a similar state is: *(1995)*

a. 0.53 Å
b. 1.06 Å
c. 0.17 Å
d. 0.265 Å

25. The energy of an electron in the n^{th} Bohr orbit of hydrogen atom is: *(1992)*

a. $\frac{-13.6}{n^4}$eV
b. $\frac{-13.6}{n^3}$eV
c. $\frac{-13.6}{n^2}$eV
d. $\frac{-13.6}{n}$eV

26. Which of the following statements do not form a part of Bohr's model of hydrogen atom? *(1989)*

a. Energy of the electrons in the orbits are quantised.
b. The electron in the orbit nearest the nucleus has the lowest energy.
c. Electrons revolve in different orbits around the nucleus.
d. The position and velocity of the electrons in the orbit cannot be determined simultaneously.

27. The spectrum of He is expected to be similar to that: *(1988)*

a. H
b. Li^+
c. Na
d. He^+

28. If r is the radius of the first orbit, the radius of n^{th} orbit of H-atom is given by: [MR*] *(1988)*

a. rn^2
b. rn
c. r/n
d. r^2n^2

Towards Quantum Mechanical Model of The Atom

29. A 0.66 kg ball is moving with a speed of 100 m/s. The associated wavelength will be: ($h = 6.6 \times 10^{-34}$ Js) [MR*] *(2010 Mains)*

a. 6.6×10^{-32} m
b. 6.6×10^{-34} m
c. 1.0×10^{-35} m
d. 1.0×10^{-32} m

30. If uncertainty in position and momentum are equal, then uncertainty in velocity is: [MR*] *(2008)*

a. $\sqrt{\frac{h}{\pi}}$
b. $\frac{1}{2m}\sqrt{\frac{h}{\pi}}$
c. $\sqrt{\frac{h}{2\pi}}$
d. $\frac{1}{m}\sqrt{\frac{h}{\pi}}$

31. The measurement of the electron position is associated with an uncertainty in momentum, which is equal to 1×10^{-18} g cm s^{-1}. The uncertainty in electron velocity is (mass of an electron is 9×10^{-28} g) *(2008)*

a. 1×10^{5} cm s^{-1} b. 1×10^{11} cm s^{-1}

c. 1×10^{9} cm s^{-1} d. 1×10^{6} cm s^{-1}

32. Given: The mass of electron is 9.11×10^{-31} kg, Planck constant is 6.626×10^{-34} Js, the uncertainty involved in the measurement of velocity within a distance of 0.1 Å is: *(2006)*

a. 5.79×10^{6} ms^{-1} b. 5.79×10^{7} ms^{-1}

c. 5.79×10^{8} ms^{-1} d. 5.79×10^{9} ms^{-1}

33. The uncertainty in momentum of an electron is 1×10^{-5} m/s. The uncertainty in its position will be ($h = 6.62 \times 10^{-34}$ kg m^2/s): *(1999)*

a. 1.05×10^{-28} m b. 1.05×10^{-20} m

c. 5.27×10^{-30} m d. 5.25×10^{-28} m

34. The de-Broglie wavelength of a particle with mass 1 g and velocity 100 m/s is: *(1999)*

a. 6.63×10^{-33} m b. 6.63×10^{-34} m

c. 6.63×10^{-35} m d. 6.65×10^{-36} m

35. The position of both, an electron and a helium atom is known within 1.0 mm. Further the momentum of the electron is known within 5.0×10^{-26} kg ms^{-1}. The minimum uncertainty in the measurement of the momentum of the helium atom is: *(1998)*

a. 50 kg ms^{-1} b. 80 kg ms^{-1}

c. 80×10^{-26} kg ms^{-1} d. 5.0×10^{-26} kg ms^{-1}

36. Uncertainty in position of an electron (mass = 9.1×10^{-28} g) moving with a velocity of 3×10^{4} cm/sec accurate upto 0.001% will be (Use $h/(4\pi)$ in uncertainty expression where $h = 6.626 \times 10^{-27}$ erg-second) *(1995)*

a. 5.76 cm b. 7.68 cm

c. 1.93 cm d. 3.84 cm

Quantum Mechanical Model of Atom

37. The relation between n_m, (n_m = the number of permissible values of magnetic quantum number (m)) for a given value of azimuthal quantum number (l), is *(2023)*

a. $n_m = \ell + 2$ b. $\ell = \frac{n_m - 1}{2}$

c. $\ell = 2n_m + 1$ d. $n_m = 2\ell^2 + 1$

38. **Incorrect** set of quantum numbers from the following is: *(2023-Manipur)*

a. $n = 4, l = 3, m_l = -3, -2, -1, 0, +1, +2, +3, m_s = -1/2$

b. $n = 5, l = 2, m_l = -2, -1, +1, +2, m_s = +1/2$

c. $n = 4, l = 2, m_l = -2, -1, 0, +1, +2, m_s = -1/2$

d. $n = 5, l = 3, m_l = -3, -2, -1, 0, +1, +2, +3, m_s = +1/2$

39. Given below are two statements: *(2023-Manipur)*

Statement I: The value of wave function, Ψ depends upon the coordinates of the electron in the atom.

Statement II: The probability of finding an electron at a point within an atom is proportional to the orbital wave function.

In the light of the above statements, choose the **correct** answer from the options given below:

a. **Statement I** is true but **Statement II** is false.

b. **Statement I** is true but **Statement II** is true.

c. Both **Statement I** and **Statement II** are true.

d. Both **Statement I** and **Statement II** are false.

40. Match List-I with List-II: *(2022 Re)*

	List-I (quantum number)		List-II (orbital)
A.	$n = 2, l = 1$	I.	2 *s*
B.	$n = 3, l = 2$	II.	3 *s*
C.	$n = 3, l = 0$	III.	2 *p*
D.	$n = 2, l = 0$	IV.	3 *d*

Choose the **correct answer** from the options given below:

a. A-III, B-IV, C-II, D-I b. A-III, B-IV, C-I, D-II

c. A-IV, B-III, C-I, D-II d. A-IV, B-III, C-II, D-I

41. Identify the incorrect statements from the following. *(2022)*

a. The shapes of d_{xy}, d_{yz}, and d_{zx} orbitals are similar to each other; and $dx^2 - y^2$ and d_{z^2} are similar to each other.

b. All the five 5d orbitals are different in size when compared to the respective 4d orbitals.

c. All the five 4d orbitals have shapes similar to the respective 3d orbitals.

d. In an atom, all the five 3d orbitals are equal in energy in free state.

42. The number of angular nodes and radial nodes in 3s orbital are [MR*] *(2020-Covid)*

a. 1 and 0, respectively b. 3 and 0, respectively

c. 0 and 1, respectively d. 0 and 2, respectively

43. 4d, 5p, 5f and 6p orbitals are arranged in the order of decreasing energy. The correct option is [MR*] *(2019)*

a. 5f > 6p > 5p > 4d b. 6p > 5f > 5p > 4d

c. 6p > 5f > 4d > 5p d. 5f > 6p > 4d > 5p

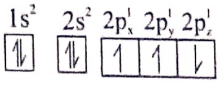
44. Which one is a wrong statement? *(2018)*

a. Total orbital angular momentum of electron in 's' orbital is equal to zero

b. An orbital is designated by three quantum numbers while an electron in an atom is designated by four quantum numbers

c. The value of m for d_{z^2} is zero

d. The electronic configuration of N atom is



45. Which one is the wrong statement? [MR*] *(2017-Delhi)*

a. The energy of 2s orbital is less than the energy of 2p orbital in case of hydrogen like atoms

b. de-Broglie's wavelength is given by $\lambda = \frac{h}{mv}$, where m = mass of the particle, v = group velocity of the particle

c. The uncertainty principle is $\Delta E \times \Delta t \geq \frac{h}{4\pi}$

d. Half-filled and fully filled orbitals have greater stability due to greater exchange energy, greater symmetry and more balanced arrangement

46. Which of the following pairs of d-orbitals will have electron density along the axes? *(2016 - II)*

a. $d_{z^2}, d_{x^2-y^2}$ b. $d_{xy}, d_{x^2-y^2}$

c. d_{z^2}, d_{xz} d. d_{xz}, d_{yz}

47. How many electrons can fit in the orbital for which: n = 3 and l = 1? *(2016 - II)*

a. 10 b. 14

c. 2 d. 6

48. Two electrons occupying the same orbital are distinguished by: *(2016 - I)*

a. Spin quantum number

b. Principal quantum number

c. Magnetic quantum number

d. Azimuthal quantum number

49. Which is the correct order of increasing energy of the listed orbitals in the atom of titanium?
(Atomic number Z = 22): *(2015 Re)*

a. 3s 3p 4s 3d b. 3s 4s 3p 3d

c. 4s 3s 3p 3d d. 3s 3p 3d 4s

50. The angular momentum of electron in '*d*' orbital is equal to: *(2015)*

a. $2\sqrt{3}\hbar$ b. $0\hbar$

c. $\sqrt{6}\hbar$ d. $\sqrt{2}\hbar$

51. What is the maximum number of orbitals that can be identified with the following quantum numbers:
n = 3, l = l, m_l = 0? *(2014)*

a. 2 b. 3

c. 4 d. 1

52. What is the maximum number of electrons that can be associated with the following set of quantum numbers?
n = 3, ℓ = 1 and m = –1. *(2013)*

a. 10 b. 6

c. 4 d. 2

53. Maximum number of electrons in a subshell with l = 3 and n = 4 is: *(2012 Pre)*

a. 14 b. 16

c. 10 d. 12

54. The correct set of four quantum numbers for the valence electron of rubidium atom (Z = 37) is: *(2012 Pre)*

a. 5, 1, 1, +1/2 b. 6, 0, 0, +1/2

c. 5, 0, 0, +1/2 d. 5, 1, 0, +1/2

55. The orbital angular momentum of a *p*-electron is given as: *(2012 Mains)*

a. $\sqrt{\frac{3}{2}}\frac{h}{\pi}$ b. $\sqrt{6}\frac{h}{2\pi}$

c. $\frac{h}{\sqrt{2}\pi}$ d. $\sqrt{3}\frac{h}{2\pi}$

56. The total number of atomic orbitals in fourth energy level of an atom is: *(2011 Pre)*

a. 4 b. 8

c. 16 d. 32

57. If n = 6, the correct sequence for filling of electrons will be: [MR*] *(2011 Pre)*

a. $ns \rightarrow (n-2)f \rightarrow (n-1)d \rightarrow np$

b. $ns \rightarrow (n-1)d \rightarrow (n-2)f \rightarrow np$

c. $ns \rightarrow (n-2)f \rightarrow np \rightarrow (n-1)d$

d. $ns \rightarrow np(n-1)d \rightarrow (n-2)f$

58. Which of the following is not permissible arrangement of electrons in an atom? *(2009)*

a. n = 5, ℓ = 3, m = 0, s = +1/2

b. n = 3, ℓ = 2, m = –3, s = –1/2

c. n = 3, ℓ = 2, m = –2, s = –1/2

d. n = 4, ℓ = 0, m = 0, s = –1/2

59. Maximum number of electrons in a subshell of an atom is determined by the following: [MR*] *(2009)*

a. $2l + 1$ b. $4l - 2$

c. $2n^2$ d. $4l + 2$

60. Consider the following sets of quantum numbers:

	n	l	m	s
(i)	3	0	0	+ 1/2
(ii)	2	2	1	+ 1/2
(iii)	4	3	– 2	– 1/2
(iv)	1	0	– 1	– 1/2
(v)	3	2	3	+ 1/2

Which of the following sets of quantum number is not possible? [MR*] *(2007)*

a. (i), (ii), (iii) and (iv) b. (ii), (iv) and (v)

c. (i) and (iii) d. (ii), (iii) and (iv)

61. The orientation of an atomic orbital is governed by: *(2006)*

a. Azimuthal quantum number

b. Spin quantum number

c. Magnetic quantum number

d. Principal quantum number

62. The following quantum numbers are possible for how many orbital $n = 3$, $\ell = 2$, $m = +2$? *(2001)*

a. 1 b. 2
c. 3 d. 4

63. For which of the following sets of four quantum numbers, an electron will have the highest energy? *(1994)*

	n	l	m	s
a.	3	2	1	+1/2
b.	4	2	–1	+1/2
c.	4	1	0	–1/2
d.	5	0	0	–1/2

64. Electronic configuration of calcium atom can be written as: *(1992)*

a. [Ne] $4p^2$ b. [Ar] $4s^2$
c. [Ne] $4s^2$ d. [Kr] $4p^2$

65. In a given atom no two electrons can have the same values for all the four quantum numbers. This is called: *(1991)*

a. Hund's Rule
b. Aufbau principle
c. Uncertainty principle
d. Pauli's Exclusion principle

66. For azimuthal quantum number $l = 3$, the maximum number of electrons will be: *(1991)*

a. 2 b. 6
c. 0 d. 14

67. The order of filling of electrons in the orbitals of an atom will be: *(1991)*

a. 3*d*, 4*s*, 4*p*, 4*d*, 5*s* b. 4*s*, 3*d*, 4*p*, 5s, 4*d*
c. 5*s*, 4*p*, 3*d*, 4*d*, 5*s* d. 3*d*, 4*p*, 4*s*, 4*d*, 5*s*

68. The electronic configuration of Cu (atomic number 29) is: *(1991)*

a. $1s^2, 2s^22p^6, 3s^23p^6, 4s^23d^9$
b. $1s^2, 2s^22p^6, 3s^23p^63d^{10}, 4s^1$
c. $1s^2, 2s^22p^6, 3s^23p^6, 4s^24p^6, 5s^25p^1$
d. $1s^2, 2s^22p^6, 3s^23p^6, 4s^24p^63d^3$

69. The total number of electrons that can be accommodated in all the orbitals having principal quantum number 2 and azimuthal quantum number 1 are: *(1991)*

a. 2 b. 4
c. 6 d. 8

70. An ion has 18 electrons in the outermost shell, it is: *(1990)*

a. Cu^+ b. Th^{4+}
c. Cs^+ d. K^+

71. Number of unpaired electrons in N^{2+} is/are *(1989)*

a. 2 b. 0
c. 1 d. 3

72. The maximum number of electrons in a subshell is given by the expression: *(1989)*

a. $4l - 2$ b. $4l + 2$
c. $4l + 2$ d. $2n^2$

73. The number of spherical nodes in 3*p* orbitals are/is: *(1988)*

a. One b. Three
c. None d. Two

Nuclear Chemistry

74. $_{92}U^{235}$ nucleus absorb a neutron and disintegrate in $_{54}Xe^{139}$, $_{38}Sr^{94}$ and *X* so, what will be the product *X*? *(2002)*

a. 3-neutrons b. 2-neutrons
c. α-particle d. β-particle

75. If a $_a^bX$ species emits firstly a positron, then two α and two β and in last one α is also emitted and finally convert into $_d^cY$ species so correct relation will be: [MR*] *(2001)*

a. c = b – 12, d = a – 5 b. a = c – 8, d = b – 1
c. a = c – 6, d = b – 0 d. a = c – 4, a = b – 2

76. Sulphur = 35 (34.96903 amu) emits a β-particle but no γ-ray. The product is chlorine = 35 (34.96885) amu. The maximum energy emitted by the β-particle is: *(1999)*

a. 16.758 MeV b. 1.6758 Mev
c. 0.16758 MeV d. 0.016758 MeV

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Answer Key

1. (a)	**2.** (d)	**3.** (a)	**4.** (a)	**5.** (a)	**6.** (a)	**7.** (d)	**8.** (b)	**9.** (c)	**10.** (c)
11. (c)	**12.** (c)	**13.** (d)	**14.** (b)	**15.** (b)	**16.** (d)	**17.** (a)	**18.** (d)	**19.** (b)	**20.** (a)
21. (d)	**22.** (d)	**23.** (d)	**24.** (c)	**25.** (c)	**26.** (d)	**27.** (b)	**28.** (a)	**29.** (c)	**30.** (b)
31. (c)	**32.** (a)	**33.** (c)	**34.** (a)	**35.** (d)	**36.** (c)	**37.** (b)	**38.** (b)	**39.** (a)	**40.** (a)
41. (a)	**42.** (d)	**43.** (a)	**44.** (d)	**45.** (a)	**46.** (a)	**47.** (c)	**48.** (a)	**49.** (a)	**50.** (c)
51. (d)	**52.** (d)	**53.** (a)	**54.** (c)	**55.** (c)	**56.** (c)	**57.** (a)	**58.** (b)	**59.** (d)	**60.** (b)
61. (c)	**62.** (a)	**63.** (b)	**64.** (b)	**65.** (d)	**66.** (d)	**67.** (b)	**68.** (b)	**69.** (c)	**70.** (a)
71. (c)	**72.** (c)	**73.** (a)	**74.** (a)	**75.** (a)	**76.** (c)				

Explanations

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1. (a) An Atom has three fundamental particles-electron, proton and neutron.

The mass of the electron is 9.10939×10^{-31} kg.

Neutrons and protons, both are collectively known as nucleons.

All the isotopes of a given element show same chemical properties.

Dalton's atomic theory, regarded atom as an ultimate particle of matter.

2. (d) $^{175}_{71}Lu$

Z = atomic number

Z = No. of Protons = 71

For a neutral atom, number of protons = number of electrons.

Hence, number of electrons = 71

No. of Neutrons = Mass no. – No. of Protons

= 175 – 71 = 104

(mass number, A = 175)

3. (a) Species having same number of electrons are called as isoelectronic species.

The number of electrons in CO = 6 + 8 = 14

CN^- = 6 + 7 + 1 = 14

NO^+ = 7 + 8 – 1 = 14

C_2^{2-} = 12 + 2 = 14

So, these are isoelectronic species as they have same number of electrons.

4. (a) Since both CO and CN^- have 14 electrons, therefore these are isoelectronic (i.e. having same number of electrons).

5. (a) The number of electrons in O^{2-}, N^{3-}, F^- and Na^+ are 10 each, but number of electrons in $T1^+$ is 80.

6. (a) As, $E_p = \phi + K.E$

$\Rightarrow \quad \phi = E_p - K.E$

Given, λ = 300 nm

$E_p = \frac{hc}{\lambda} = 3.99 \times 10^5$ J mol^{-1}

As, K.E = 1.68×10^5 J mol^{-1}

$\therefore \quad \phi = E_p - K.E = (3.99 - 1.68) \times 10^5$

$= 2.31 \times 10^5$ J mol^{-1}

7. (d) The formula to calculate wavelength is:

$$\lambda = \frac{c}{\nu}$$

Where, c is the speed of electromagnetic radiation in vacuum.

and, ν is the frequency

On substituting the given values in above formula

$$= \frac{3.00\times10^8 \text{ ms}^{-1}}{1368 \text{ kHz}}$$

$$= \frac{3.00\times10^8 \text{ ms}}{1368\times10^3 \text{ s}^{-1}}$$

= 219.3 m

8. (b) The Balmer series of lines are the only lines in the hydrogen spectrum which appear in the visible region of the electromagnetic spectrum.

9. (c) The formula to calculate energy in terms of wavelength is: $E = \frac{hc}{\lambda}$

On substituting the values in above formula, we get:

$$E = \frac{6.63\times10^{-34}\times3\times10^8}{45\times10^{-9}} = 4.42\times10^{-18} \text{ J}$$

10. (c) According to formula of energy:

$$E = \frac{hc}{\lambda} \text{ or } h\nu$$

Where ν represents the frequency of light and c is speed of light

Also, $\frac{c}{\lambda} = \nu \quad \Rightarrow \quad \lambda = \frac{3\times10^8}{6\times10^{15}} = 50$ nm

11. (c) The relation between Energy and wavelength is: $E = \frac{hc}{\lambda}$

$$\frac{E_1}{E_2} = \frac{hc}{\lambda_1} \times \frac{\lambda_2}{hc} \quad \Rightarrow \frac{1}{2} = \frac{\lambda_2}{\lambda_1}$$

$$\Rightarrow \lambda_1 = 2\lambda_2$$

12. (c) Applying $\nu = \frac{c}{\lambda}$

$$\nu = \frac{c}{\lambda} = \frac{3\times10^8}{8\times10^{15}} = 0.375\times10^{-7} \text{ m} = 3.75 \times 10^{-8} \text{ nm}$$

13. (d) $E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{6.6\times10^{-34}\times3\times10^8}{3.03\times10^{-19}} = 653$ nm

14. (b) The longest wavelength means the lowest energy. We know that relation for wavelength

$$\frac{1}{\lambda} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

here $n_1 = 2, n_2 = 3$

R_H (Rydberg constant) = 109677 cm^{-1}

$$\frac{1}{\lambda} = 109677\left(\frac{1}{(2)^2} - \frac{1}{(3)^2}\right) = 15233$$

or, $\lambda = \frac{1}{15233} = 6.56\times10^{-5}$ cm $= 6.56 \times 10^{-7}$ m $= 656$ nm

15. (b) Acc. to Bohr's atomic model,

$$r \propto \frac{n^2}{z}$$

For 3rd orbit of Li^{+2} : $n_1 = 3, z_1 = 3$

For 2nd orbit of He^+ : $n_2 = 2, z_2 = 2$

$$\frac{(r_3)_{Li^{+2}}}{(r_2)_{He^+}} = \frac{n_1^2}{n_2^2} \times \frac{z_2}{z_1}$$

$$\frac{(r_3)_{Li^{+2}}}{105.8\,pm} = \frac{(3)^2 \times 2}{(2)^2 \times 3}$$

$$(r_3)_{Li^{+2}} = 158.7 \text{ pm}$$

16. (d) The orbitals which are closer to nucleus are more strongly affected by the positive charged field of protons in nucleus. Whereas when we move away from nucleus & *n* (principal quantum number) increases, the effective influence of positive charged field decreases & electron in later (*n*) orbitals become loosely bounded.

17. (a) According to Bohr's theory:

$$\Delta E \propto \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

For n = 6 to n = 5:

$$\Delta E \propto \left[\frac{1}{5^2} - \frac{1}{6^2}\right] = \frac{11}{900}$$

For n = 5 to n = 3:

$$\Delta E \propto \left[\frac{1}{3^2} - \frac{1}{5^2}\right] = \frac{16}{225}$$

For n = 6 to n = 1:

$$\Delta E \propto \left[\frac{1}{1^2} - \frac{1}{6^2}\right] = \frac{35}{36}$$

For n = 5 to n = 4:

$$\Delta E \propto \left[\frac{1}{4^2} - \frac{1}{5^2}\right] = \frac{9}{400}$$

Here, least value is for n = 6 to n = 5.

$n_2 = 6, n_1 = 5$ as $E \propto \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

When $n_2^2 > n_1^2$, hydrogen will give rise to least energised photon.

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18. (d) $E_n = -K\left(\frac{Z}{n}\right)^2$

Z = 1 for hydrogen; n = 2

$$E_2 = \frac{-K \times 1}{4} \Rightarrow E_2 = 328 \text{kJ mol}^{-1}; K = 4 \times 328$$

$$E_4 = \frac{-K \times 1}{16} \Rightarrow E_4 = -4 \times 328 \times \frac{1}{16} = -82 \text{ kJ mol}^{-1}$$

19. (b) $\because E = h\nu$

$$\nu = \frac{E}{h}$$

$$\text{For H-atom, } E = \frac{-21.76 \times 10^{-19}}{n^2} \text{ J atm}^{-1}$$

$$\therefore E = -21.76 \times 10^{-19}\left(\frac{1}{4^2} - \frac{1}{1^2}\right)$$

$$= 20.40 \times 10^{-19} \text{ J atm}^{-1}$$

$$\nu = \frac{20.40 \times 10^{-19}}{6.62 \times 10^{-34}}$$

$$\nu = 3.079 \times 10^{15} \text{ s}^{-1}$$

20. (a) For hydrogen atom,
The kinetic energy is equal to negative of total energy.
The first excited state energy of orbital = –3.4eV
∴ Kinetic energy of same orbital = –(–3.4eV) = 3.4eV

21. (d) Sommerfeld modified Bohr's theory.

22. (d) $r \propto n^2$
where n = number of orbit

$\because r_1 \propto n_1^2$

$r_2 \propto n_2^2$ (Z = 1 for H-atom)

So, $\frac{r_1}{r_2} = \frac{n_1^2}{n_2^2}$

$$= \frac{0.530}{r_2} = \frac{1^2}{2^2}$$

$\therefore r_2 = 0.530 \times 4 \simeq 2.120$ Å

23. (d) The energy gap between two orbits is given by equation.

$$\Delta E = R_H\left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right]$$

Here,
$n_i = 3, n_f = 1$

Here, $\Delta E = -2.18 \times 10^{-18} \text{ J}\left[\frac{1}{9} - \frac{1}{1}\right]$

$\Delta E = -2.18 \times 10^{-18} \text{ J} \times \frac{-8}{9} = 1.936 \times 10^{-18} \text{ J}$

Also 1J = 10^7 ergs

Thus, $\Delta E = 1.936 \times 10^{-18} \times 10^7$ ergs

$= 1.936 \times 10^{-11}$ ergs

$= 0.1936 \times 10^{-10}$ ergs

24. (c) In ground state, the value of n for hydrogen atom = 1
Hence, radius of hydrogen atom (*r*) in ground state = 0.53 Å
Now, atomic no. of Li (*Z*) = 3

Hence, radius of Li^{2+} ion $= r \times \frac{n^2}{Z}$

$$= 0.53 \times \frac{(1)^2}{3} = 0.17 \text{ Å}$$

25. (c) Energy of an electron in n^{th} Bohr orbit of hydrogen atom

$$= \frac{-13.6}{n^2} \text{eV}$$

26. (d) The statement given in (d) is in accordance with Heisenberg Uncertainty principle.

27. (b) Both He and Li^+ contain 2 electrons each. Hence, their spectrum will be similar.

28. (a) $r_n = \frac{n^2h^2}{4\pi^2 me^2 Z} = \frac{0.529\,n^2}{Z}$

For H-atom, Z = 1

$r_1 = r$

$\therefore r_n = \frac{r \times n^2}{1} = rn^2$

29. (c) de-Broglie wavelength is given by λ and it is calculated as:

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{6.6\times10^{-34}}{0.66\times100}$$

$= 1 \times 10^{-35}$ m

30. (b) According to Heisenberg's principle:

$$\Delta x \cdot \Delta p \geq \frac{h}{4\pi}$$

Now, $\Delta x = \Delta p$ $\{\Delta p = m\Delta v\}$

$$\therefore\ m^2\Delta v^2 \geq \frac{h}{4\pi}$$

$$\Delta v = \frac{1}{2m}\sqrt{\frac{h}{\pi}}$$

31. (c) According to Heisenberg uncertainty:

principle, $\Delta p.\Delta x \geq \frac{h}{4\pi}$

But according to question, electron position (Δx) is associated with momentum

so, $(\Delta p) = 1 \times 10^{-18}$ gcm/sec

$m\Delta v = 1 \times 10^{-18}$ $\because$ $\Delta p = m\Delta v$

$$\Delta v = \frac{1\times10^{-18}}{9.1\times10^{-28}}$$ $\because$ mass of electron $= 9.1 \times 10^{-28}$ gm

$\Delta v = 1.1 \times 10^{9}$ cm sec^{-1}

32. (a) According to Heisenberg's uncertainty principle:

$$\Delta x.\ \Delta p \geq \frac{h}{4\pi}$$

$$\Delta x.\ m\Delta v \geq \frac{h}{4\pi}$$

$$\Delta v \geq \frac{h}{4\pi\Delta x\, m} = \frac{6.626\times10^{-34}}{4\times3.14\times10^{-10}\times9.1\times10^{-31}} = 0.579\times10^{7}$$

$\Delta v = 5.79 \times 10^{6}$ ms^{-1}

33. (c) According to Heisenberg uncertainty principle:

$$\Delta p \times \Delta x \geq \frac{h}{4\pi}$$

$$\Delta x = \frac{6.62\times10^{-34}\times7}{4\times1\times10^{-5}\times22}$$

$\approx 5.27\times10^{-30}$ m

34. (a) The formula to calculate wavelength in terms of momentum is:

$$\lambda = \frac{h}{P} = \frac{6.62\times10^{-34}\ \text{kgm}^2/\text{s}}{10^{-3}\text{kg}\times100\text{m/s}}$$

$\lambda = 6.63 \times 10^{-33}$ m.

35. (d) By Heisenberg uncertainty principle:

$$\Delta x \times \Delta p \geq \frac{h}{4\pi}$$

When the position of electron and helium atom is known and momentum of electron is also known within a range, therefore, the momentum of helium atom is equal to the momentum of electron i.e., 5×10^{-26} kg ms^{-1}.

36. (c) Mass of an electron (m) $= 9.1 \times 10^{-28}$ g

Velocity of electron (v) $= 3 \times 10^{4}$ cm/s

Accuracy $= 0.001\% = \frac{0.001}{100}$ and

Planck's constant (h) $= 6.626 \times 10^{-27}$ erg-second.

We know that actual velocity of the electron (Δv)

$$= 3\times10^{4} \times \frac{0.001}{100} = 0.3 \text{ cm/s}$$

Therefore, uncertainty in the position of the electron

$$(\Delta x) = \frac{h}{4\pi m\Delta v} = \frac{6.626\times10^{-27}}{4\pi\times\left(9.1\times10^{-28}\right)\times0.3} = 1.93 \text{ cm}$$

37. (b) $n_m = 2l + 1$

As there are $(2l + 1)$ number of permissible values of magnetic quantum number.

Hence, $l = \frac{n_m - 1}{2}$

38. (b) The incorrect set of quantum numbers given in:

$$n = 5,\ l = 2,\ m = -2, -1, 0, +1, +2,\ m_s = +\frac{1}{2}$$

39. (a) The probability of finding an electron at a point within an atom is directly proportional to the square of orbital wave function.

40. (a)

Value of l	0	1	2	3
Subshell	s	p	d	f

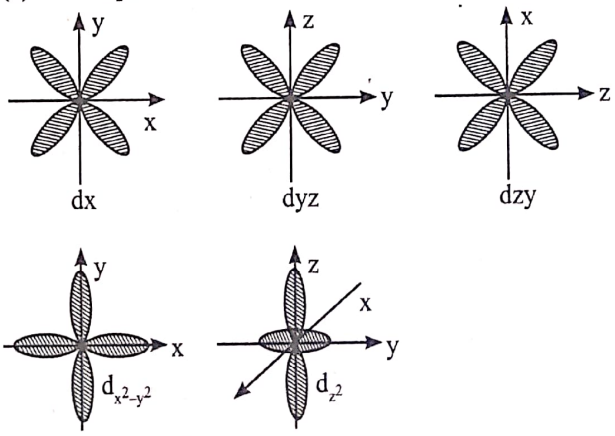
$\therefore$ $n = 2, l = 1$ $\Rightarrow$ $2p$

$n = 3, l = 2$ $\Rightarrow$ $3d$

$n = 3, l = 0$ $\Rightarrow$ $3s$

$n = 2, l = 0$ $\Rightarrow$ $2s$

41. (a) The shapes of all d orbitals are given as



From the above figures it is clear that shape of dz^2 is not similar to $d_{x^2-y^2}$.

42. (d) Number of radial nodes $= n - \ell - 1$

Number of angular nodes $= \ell$

For 3s orbital,

$\ell = 0$

- Number of radial nodes $= 3 - 0 - 1 = 2$
- Number of angular nodes $= 0$

43. (a)

$n \quad l$

(n + 1) value for, 4d = 4 + 2 = 6

5p = 5 + 1 = 6

5f = 5 + 3 = 8

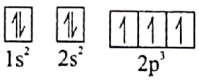
6p = 6 + 1 = 7

Lower value of (n + *l*) signifies lower energy.

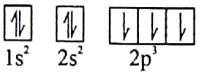
In case of 4d and 5p, value of (n + l) is equal, therefore, the one with lower value of "n" has lower energy. So, 4d has less energy in comparison to 5p.

∴ Correct order of energy will be 5f > 6p > 5p > 4d

44. (d) According to Hund's Rule of maximum multiplicity, the pairing of electrons in the orbitals belonging to the same sub-shell (p, d or f) does not take place until each orbital belonging to that subshell has got one electron each i.e., it is singly occupied. Hence, correct electronic configuration of N-atom is:



OR



∵ Option (d) violates Hund's Rule.

45. (a) For a single electronic species like H, energy depends on value of n and does not depend on l.

Hence, energy of 2s and 2p orbital is equal for H-like species.

46. (a) Among *d*-orbitals, d_{z^2} & $d_{x^2-y^2}$ have their electron densities orientated along the axes while dxy, dxz and dyz orbitals oriented between the axes.

47. (c) When n = 3 and *l* = 1, then orbital is 3p, so total number of electron that can be filled are 6 as in any orbital only 2 electron can accumulate.

48. (a) 2 electron occupying the same orbital can be distinguished using their spin quantum number (m_s) where one is clockwise (↑) and other is anti-clockwise (↓). In such case, the value of spin quantum number changes rest all quantum number remains the same.

49. (a) Atomic number of titanium is 22. According to Aufbau principle, an increasing order of energy for filling up of electrons is given by: 3s < 3p < 4s < 3d

50. (c) Angular momentum = $\sqrt{\ell(\ell+1)}\frac{h}{2\pi}$

For d orbital, $\ell = 2$

So, angular momentum = $\sqrt{2(2+1)}\frac{h}{2\pi} = \sqrt{6}\frac{h}{2\pi}$

$\frac{h}{2\pi} = \hbar$ → called as Planck's reducing constant or Dirac constant.

51. (d) For $n = 3, l = 0, 1, 2$ and for $l = 1, m = -1, 0, +1$, it suggests that it is 3p orbital and magnetic quantum no. suggest that it is $3p_z$.

−1	0	−1
↿⇂	↿⇂	↿⇂
p_x	p_y	p_z

So, for $n = 3, l = +1, m_l = 0$, only 1 set is possible.

Thus, the maximum number of orbitals identified by the given quantum no. is only one, i.e., $3p_z$.

52. (d)

$n = 3 \qquad l = 1 \qquad m_l = -1$

l = 1 for *p* orbital

Since $m_l = -1$, so orbital must be $3p_x$ or $3p_y$, where number of electron in each orbital will be 2.

53. (a) n = 4 and $\ell = 3$, this represent = 4f

Total number of electrons in a sub shell = $2(2\ell + 1)$

$= 2(2 \times 3 + 1)$

$= 14$

54. (c) $_{37}Rb \rightarrow 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1$

for 5s → n = 5, $\ell = 0$, m = 0 and $s = \pm\frac{1}{2}$

55. (c) Orbital angular momentum = $\sqrt{\ell(\ell+1)}\frac{h}{2\pi}$

For p-orbital $\ell = 1$

$m = \sqrt{\ell(\ell+1)}\frac{h}{2\pi}$

$m = \sqrt{1(1+1)}\frac{h}{2\pi} \Rightarrow m = \sqrt{2}\frac{h}{2\pi} \Rightarrow m = \frac{h}{\sqrt{2}\pi}$

56. (c) Number of atomic orbitals are calculated as n^2 so for 4th energy level, it will be 16 orbitals.

57. (a) If n = 6 then correct sequence for filling of electron is you have to follow (n + ℓ) rule.

value of ℓ for orbital → s = 0

value of ℓ for orbital → p = 1

value of ℓ for orbital → d = 2

value of ℓ for orbital → f = 3

Arrange the sequence to fill electrons in an increasing order of (n+l) value.

a. ns → (n − 2) f → (n − 1)d → np

↓	↓	↓	↓	
	6 s	4f	5d	6p
	6 + 0	4 + 3	5 + 2	6 + 1
(n + ℓ)	↓	↓	↓	↓
	6	7	7	7

When value of n + ℓ is equal for more than one sub-shell, then increasing order of n is correct order.

58. (b) Arrangement $n = 3 \quad l = 2 \quad m_l = -3$ and $m_s = -1/2$ is not possible as value of m_l should vary from $-l$ to $+l$ here −3 value is not possible.

59. (d) For a given shell, number of orbital = $(2\ell + 1)$

and each orbital contains = 2 electron

So, maximum number of electron = $2(2\ell+1) = 4\ell + 2$

60. (b) (ii) Option is not possible because for any value of *n*, l varies from 0 to $(n - 1)$ thus for $n = 2$, l can be only 0, 1

61.

62.

63.

64.

65.

66.

67.

68.

69.

(iv) Option is not possible because for $l = 0$, $m_l = 0$.

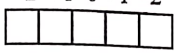
(v) Option is not possible because for $l = 2$, value of m_l varies from -2 to $+2$.

61. (c) Orientation of atomic orbital is governed by magnetic quantum number (m_l) which varies from $-l$ to $+l$.

62. (a) n = 3, l = 2, m = +2

It symbolises one of the five d - orbitals (3d)

m = +2 +1 0 –1 –2



63. (b) Energy of electron depends on the value of $(n + l)$. The sub shell are 3d, 4d, 4p and 5s, 4d has highest value of (n+l) and hence has highest energy.

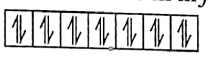
64. (b) Atomic No. of Ca = 20

$\therefore$ Electronic configuration of Ca = $[Ar]4s^2$

65. (d) This is a Pauli's Exclusion principle which states that "No two electrons can have the same value for all the four quantum numbers.

66. (d) l = 3 means f-subshell

Maximum no. of electrons in in *f*-subshell = 14

f-subshell = 

67. (b) According to Aufbau Principle, in the ground state of the atoms, the orbitals are filled in order of their increasing energies.

68. (b) Atomic number of Cu is 29. Thus, the electronic configuration of Cu is $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}, 4s^1$.

69. (c) $n = 2, l = 1$

It means 2*p*-orbital

Total no. of electrons that can be accommodated in 2*p* orbitals = 6 (px,py, pz)

70. (a) Atomic number of Cu is 29. Electronic configuration of $Cu^+ = 2, 8, 18$

71. (c) N_2 has 14 electrons. When it forms N^{2+}, remaining electrons will become 5.

The electronic configuration of N^{2+} is $1s^2 2s^2 2p_x^1$

$\therefore$ No. of unpaired electrons = 1

72. (c) No. of orbitals in a sub-shell = $2l + 1$

$\Rightarrow$ No. of electrons = $2(2l + 1) = 4l + 2$

73. (a) No. of radial nodes in 3*p*-orbital = $n - l - 1$

For 3p orbital, $l = 1$

Hence, no. of nodes = $3 - 1 - 1 = 1$

74. (a) $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{139}_{54}Xe + ^{94}_{38}Sr + x$

On L.H.S.

Sum of mass no. = 235 + 1 = 236

Sum of atomic no. = 92 + 0 = 92

On R.H.S.

Sum of mass no. = 139 + 94 = 233

$\therefore$ mass on x = 236 – 233 = 3

Sum of atomic no. = 54 + 38 = 92

$\therefore$ Charge on x = 0

Product x is 3 neutrons.

75. (a) $^{b}_{a}X \xrightarrow{-^{0}_{+1}\beta} {}^{b}_{a-1}X \xrightarrow{-2^{4}_{2}He} {}^{b-8}_{a-5}X \xrightarrow{-2^{0}_{-1}\beta} {}^{b-8}_{a-3}X \xrightarrow{-2^{4}_{2}He} {}^{b-12}_{a-5}X \equiv {}^{c}_{d}X$

c = b – 12 and d = a – 5

76. (c) $_{16}S^{35} \xrightarrow{\beta^-} {}_{17}C^{35}$

Mass defect = mass of S – mass of Cl

$\Delta m = 34.96903 - 34.96885 = 0.00018$ g

Energy = $\Delta \times 931$ MeV

Energy = 0.00018×931 MeV = 0.16758 MeV

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CHAPTER 3

Classification of Elements and Periodicity in Properties

Modern Periodic Law, Nomenclature of Elements

1. The IUPAC name of an element with atomic number 119 is. *(2022)*

a. Ununcotium
b. Ununennium
c. Unnilennium
d. Unununnium

2. Identify the incorrect match [MR*] *(2020)*

	Name		IUPAC Official Name
(A)	Unnilunium	(i)	Mendelevium
(B)	Unniltrium	(ii)	Lawrencium
(C)	Unnilhexium	(iii)	Seaborgium
(D)	Unununnium	(iv)	Darmstadtium

a. (B), (ii)
b. (C), (iii)
c. (D), (iv)
d. (A), (i)

Electronic Configurations and Types of Elements (s, p, d and f-Blocks)

3. The element Z = 114 has been discovered recently. It will belong to which of the following family group and electronic configuration? [MR*] *(2017-Delhi)*

a. Nitrogen family, [Rn] $5f^{14}6d^{10}7s^27p^6$
b. Halogen family, [Rn] $5f^{14}6d^{10}7s^27p^5$
c. Carbon family, [Rn] $5f^{14}6d^{10}7s^27p^2$
d. Oxygen family, [Rn] $5f^{14}6d^{10}7s^27p^4$

4. The number of d-electrons in Fe^{2+} (Z = 26) is not equal to the number of electrons in which one of the following? *(2015)*

a. p-electrons in Cl (Z = 17)
b. d-electrons in Fe (Z = 26)
c. p-electrons in Ne (Z = 10)
d. s-electrons in Mg (Z = 12)

5. A nucleus of an alkaline earth metal undergoes radioactive decay by emission of three α-particles in succession. The group of the periodic table to which the resulting daughter element would belong is: [MR*] *(2005)*

a. Group 14
b. Group 16
c. Group 4
d. Group 6

6. Which of the following configuration is correct for iron? *(1999)*

a. $1s^2, 2s^22p^6, 3s^23p^63d^5$
b. $1s^2, 2s^22p^6, 3s^23p^6, 4s^23d^5$
c. $1s^2, 2s^22p^6, 3s^23p^6, 4s^23d^7$
d. $1s^2, 2s^22p^6, 3s^23p^6, 3d^6, 4s^2$

7. Which of the following has more unpaired d-electrons? *(1999)*

a. Zn^+
b. Fe^{2+}
c. N^{3+}
d. Cu^+

8. The electronic configuration of an element is $1s^22s^22p^63s^23p^3$. What is the atomic number of the element, which is just below the above element in the periodic table? *(1995)*

a. 33
b. 34
c. 36
d. 49

9. If the atomic number of an element is 33, it will be placed in the periodic table in the: *(1993)*

a. First group
b. Third group
c. Fifth group
d. Seventh group

10. The electronic configuration of four elements are given below. Which elements does not belong to the same family as others? *(1989)*

a. $[Xe]4f^{14}5d^{10}1s^2$
b. $[Kr]4d^{10}5s^2$
c. $[Ne]3s^23p^5$
d. $[Ar]3d^{10}4s^2$

Periodic Trends in Properties of Elements

11. The element expected to form largest ion to achieve the nearest noble gas configuration is: *(2023)*

a. Na
b. O
c. F
d. N

Given below are two statements: one is labelled as *(2023-Manipur)*

Assertion (A) and the other is labelled as **Reason (R)**

Assertion (A): Ionisation enthalpy increases along each series of the transition elements from left to right. However, small variations occur.

Reason (R): There is corresponding increase in nuclear charge which accompanies the filling of electrons in the inner d-orbitals.

In the light of the above statements, choose the **most appropriate** answer form the options given be:

a. **(A)** is correct but **(R)** is not correct.

b. **(A)** is not correct but **(R)** is correct.

c. Both **(A)** and **(R)** are correct and **(R)** is the correct explanation of **(A)**.

d. Both **(A)** and **(R)** are correct **(R)** is **not** the correct explanation of **(A)**.

13. Which one of the following represents all isoelectronic species? **[MR*]** *(2023-Manipur)*

a. Na^+, Cl^-, O^-, NO^+ b. N_2O, N_2O_4, NO^+, NO

c. Na^+, Mg^{2+}, O^-, F^- d. Ca^{2+}, Ar, K^+, Cl^-

14. The **correct** sequence given below containing neutral, acidic, basic and amphoteric oxide each, respectively, is *(2023-Manipur)*

a. NO, ZnO, CO_2, CaO b. ZnO, NO, CaO, CO_2

c. NO, CO_2, ZnO, CaO d. NO, CO_2, CaO, ZnO

15. The correct order of first ionization enthalpy for the given four elements is: *(2022 Re)*

a. C < F < N < O b. C < N < F < O

c. C < N < O < F d. C < O < N < F

16. If first ionization enthalpies of elements X and Y are 419 kJ mol^{-1} and 590 kJ mol^{-1}, respectively and second ionization enthalpies of X and Y are 3069 kJ mol^{-1} and 1145 kJ mol^{-1}, respectively. Then **correct statement** is: *(2022 Re)*

a. Both X and Y are alkaline earth metals.

b. X is an alkali metal and Y is an alkaline earth metal.

c. X is an alkaline earth metal and Y is an alkali metal.

d. Both X and Y are alkali metals.

17. From the following pairs of ions, which one is not an iso-electronic pair? *(2021)*

a. Na^+, Mg^{2+} b. Mn^{2+}, Fe^{3+}

c. Fe^{2+}, Mn^{2+} d. O^{2-}, F^-

18. For the second period elements, the correct increasing order of first ionisation enthalpy is: *(2019)*

a. Li < Be < B < C < N < C < F < Ne

b. Li < B < Be < C < O < N < F < Ne

c. Li < B < Be < C < N < O < F < Ne

d. Li < Be < B < C < O < N < F < Ne

19. In which of the following options, the order of arrangement does not agree with the variation of property indicated against it? **[MR*]** *(2016 - I)*

a. Li < Na < K < Rb (increasing metallic radius)

b. $Al^{3+} < Mg^{2+} < Na^+ < F^-$ (increasing ionic size)

c. B < C < N < O (increasing first ionization enthalpy)

d. I < Br < Cl < F (increasing electron gain enthalpy)

20. The formation of the oxide ion, $O^{2-}(g)$ from oxygen atom requires first an exothermic step and then an endothermic step as shown below:

$O(g) + e^- \rightarrow O^-(g)$; $\Delta_f H^\circ = -141$ kJ mol^{-1}

$O^-(g) + e^- \rightarrow O^{2-}(g)$; $\Delta_f H^\circ = +780$ kJ mol^{-1}

Thus, process of formation of O^{2-} in gas phase is unfavourable even though O^{2-} is isoelectronic with neon. It is due to the fact that, *(2015 Re)*

a. O^- ion has comparatively smaller size than oxygen atom

b. Oxygen is more electronegative

c. Addition of electron in oxygen results in larger size of the ion

d. Electron repulsion outweighs the stability gained by achieving noble gas configuration

21. The species Ar, K^+ and Ca^{2+} contain the same number of electrons. In which order do their radii increase? *(2015)*

a. $Ca^{2+} < Ar < K^+$ b. $Ca^{2+} < K^+ < Ar$

c. $K^+ < Ar < Ca^{2+}$ d. $Ar < K^+ < Ca^{2+}$

22. Be^{2+} is isoelectronic with which of the following ions? *(2014)*

a. Li^+ b. Na^+

c. Mg^{2+} d. H^+

23. Which of the following orders of ionic radii is correctly represented? *(2014)*

a. $Na^+ > F^- > O^{2-}$ b. $O^{2-} > F^- > Na^+$

c. $Al^{3+} > Mg^{2+} > N^{3-}$ d. $H^- > H^+ > H$

24. Identify the wrong statement in the following: *(2012 Pre)*

a. Atomic radius of the elements decreases as one moves across from left to right in the 2nd period of the periodic table

b. Amongst isoelectronic species, smaller the positive charge on the cation, smaller is the ionic radius

c. Amongst isoelectronic species, greater the negative charge on the anion, larger is the ionic radius

d. Atomic radius of the elements increases as one moves down the first group of the periodic table.

25. What is the value of electron gain enthalpy of Na^+ if IE_1 of Na = 5.1 eV? *(2011 Mains)*

a. +2.55 eV b. +10.2 eV

c. −5.1 eV d. −10.2 eV

26. Among the elements Ca, Mg, P and Cl, the order of increasing atomic radii is: *(2010 Mains)*

a. Mg < Ca < Cl < P b. Cl < P < Mg < Ca

c. P < Cl < Ca < Mg d. Ca < Mg < P < Cl

27. Which of the following represents the correct order of increasing electron gain enthalpy with negative sign for the elements O, S, F and Cl? [MR*] *(2010 Pre)*

a. S < O < Cl < F
b. Cl < F < O < S
c. O < S < F < Cl
d. F < S < O < Cl

28. The correct order of the decreasing ionic radii among the following isoelectronic species is: *(2010 Pre)*

a. $K^+ > Ca^{2+} > Cl^- > S^{2-}$
b. $Ca^{2+} > K^+ > S^{2-} > Cl^-$
c. $Cl^- > S^{2-} > Ca^{2+} > K^+$
d. $S^{2-} > Cl^- > K^+ > Ca^{2+}$

29. Amongst the elements with following electronic configurations, which one of them may have the highest ionisation energy? *(2009)*

a. [Ne] $3s^2 3p^2$
b. [Ar] $3d^{10} 4s^2 4p^3$
c. [Ne] $3s^2 3p^1$
d. [Ne] $3s^2 3p^3$

30. With which of the following electronic configuration, an atom has the lowest ionisation enthalpy? *(2007)*

a. $1s^2\ 2s^2\ 2p^3$
b. $1s^2\ 2s^2\ 2p^5\ 3s^1$
c. $1s^2\ 2s^2\ 2p^6$
d. $1s^2\ 2s^2\ 2p^5$

31. Identify the correct order of the size of the following: *(2007)*

a. $Ca^{2+} < K^+ < Ar < Cl^- < S^{2-}$
b. $Ar < Ca^{2+} < K^+ < Cl^- < S^{2-}$
c. $Ca^{2+} < Ar < K^+ < Cl^- < S^{2-}$
d. $Ca^{2+} < K^+ < Ar < S^{2-} < Cl^-$

32. Which one of the following arrangements represents the correct order of electron gain enthalpy (with negative sign) of the given atomic species? *(2005)*

a. Cl < F < S < O
b. O < S < F < Cl
c. S < O < Cl < F
d. F < Cl < O < S

33. Ionic radii are: *(2004)*

a. Inversely proportional to square of effective nuclear charge
b. Directly proportional to effective nuclear charge
c. Directly proportional to square of effective nuclear charge
d. Inversely proportional to effective nuclear charge

34. The ions O^{2-}, F^-, Na^+, Mg^{2+} and Al^{3+} are isoelectronic. Their ionic radii show: [MR*] *(2003)*

a. A significant increase from O^{2-} to Al^{3+}
b. A significant decrease from O^{2-} to Al^{3+}
c. An increase from O^{2-} to F^- and then decrease from Na^+ to Al^{3+}
d. A decrease from O^{2-} to F^- and then increase from Na^+ to Al^{3+}

35. Which of the following order is wrong? [MR*] *(2002)*

a. $NH_3 < PH_3 < AsH_3$ – Acidic
b. Li < Be < B < C – I[st] IP
c. $Al_2O_3 < MgO < Na_2O < K_2O$ – Basic
d. $Li^+ < Na^+ < K^+ < Cs^+$ – Ionic radius

36. Correct order of I[st] IP among following elements Be, B, C, N, O is: *(2001)*

a. B < Be < C < O < N
b. B < Be < C < N < O
c. Be < B < C < N < O
d. Be < B < C < O < N

37. Which statement is wrong? *(2000)*

a. Bond energy of $F_2 > Cl_2$
b. Electronegativity of F > Cl
c. F is more oxidising than Cl
d. Electron affinity of Cl > F

38. Which of the following elements has the maximum electron affinity? *(1999)*

a. I
b. Br
c. Cl
d. F

39. The first ionization potential (in eV) of Be and B, respectively are: *(1998)*

a. 8.29, 9.32
b. 9.32, 9.32
c. 8.29, 8.29
d. 9.32, 8.29

40. Which one of the following is correct order of the size of iodine species? *(1997)*

a. $I^+ > I^- > I$
b. $I^- > I > I^+$
c. $I > I^- > I^+$
d. $I > I^+ > I^-$

41. Which of the following ion is the largest in size? *(1996)*

a. K^+
b. Ca^{2+}
c. Cl^-
d. S^{2-}

42. Which of the following has the smallest size? *(1996)*

a. Al^{3+}
b. F^-
c. Na^+
d. Mg^{2+}

43. Na^+, Mg^{2+}, Al^{3+} and Si^{4+} are isoelectronic. The order of their ionic size is: *(1993)*

a. $Na^+ > Mg^{2+} < Al^{3+} < Si^{4+}$
b. $Na^+ < Mg^{2+} > Al^{3+} > Si^{4+}$
c. $Na^+ > Mg^{2+} > Al^{3+} > Si^{4+}$
d. $Na^+ < Mg^{2+} > Al^{3+} < Si^{4+}$

44. In the periodic table from left to right in a period, the atomic volume: *(1993)*

a. Decreases
b. Increases
c. Remains same
d. First decrease then increases

45. One of the characteristic properties of non-metals is that they: *(1993)*

a. Are reducing agents
b. Form basic oxides
c. Form cations by electron gain
d. Are electronegative

46. Which electronic configuration of an element has abnormally high difference between second and third ionization energy? *(1993)*

a. $1s^2, 2s^2, 2p^6, 3s^1$
b. $1s^2, 2s^2, 2p^6, 3s^1 3p^1$
c. $1s^2, 2s^2, 2p^6, 3s^2 3p^2$
d. $1s^2, 2s^2, 2p^6, 3s^2$

47. Pauling's electronegativity values for elements are useful in predicting: *(1989)*

a. Polarity of the molecules
b. Position in the E.M.F. series
c. Coordination numbers
d. Dipole moments

48. In the periodic table, with the increase in atomic number, the metallic character of an element: *(1988)*

a. Decreases in a period and increases in a group
b. Increases in a period and decreases in a group
c. Increases both in a period and the group
d. Decreases in a period and the group

Answer Key

1. (b)	2. (c)	3. (c)	4. (a)	5. (a)	6. (d)	7. (b)	8. (a)	9. (c)	10. (c)
11. (d)	12. (c)	13. (d)	14. (d)	15. (d)	16. (b)	17. (c)	18. (b)	19. (c,d)	20. (d)
21. (b)	22. (a)	23. (b)	24. (b)	25. (c)	26. (b)	27. (c)	28. (d)	29. (d)	30. (b)
31. (a)	32. (b)	33. (d)	34. (b)	35. (b)	36. (a)	37. (a)	38. (c)	39. (d)	40. (b)
41. (d)	42. (a)	43. (c)	44. (d)	45. (d)	46. (d)	47. (a)	48. (a)		

Explanations

1. (b) According to IUPAC nomenclature, one is named as un and nine is named as enn and overall name is ended with ium. Therefore, the correct name for 119 will be ununennium.

Un + un + enn + ium = 119

2. (c) Unununnium is the element that has Atomic number = 111 (Un + un + un + ium = 111)

IUPAC official name of Unununnium: Roentgenium

Thus, option c is correct.

3. (c) For p-block elements, the general configuration is ns^2np^{1-6}. As the given configuration has outermost configuration similar to p-block, it belongs to p- block. An element 114 has been discovered after 113 which belongs to Boron family. So, definitely, 114 element will belong to carbon family.

Carbon family: $[Rn]\ 5f^{14}6d^{10}7s^27p^2$

4. (a) Fe^{2+} (Z = 26) = $[Ar]3d^6$

Number of *d* electrons in Fe^{2+} = 6

Cl (Z = 17) = $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

Number of *p* electrons in Cl = 11

Mg (Z = 12) = $1s^2\ 2s^2\ 2p^6\ 3s^2$

Number of *s* electrons in Mg = 6

Ne (Z = 10) = $1s^2\ 2s^2\ 2p^6$

Number of *p* electrons in Ne = 6

5. (a) On emission of α-particle, radioactive atom reduces 2 in atomic number and 4 in atomic mass.

So, ${}^{x}_{y}A \rightarrow X^{x-2}_{y-4}$

A belongs to group 2 (Alkaline earth metal elements) on 3 successive α-particle decay undergoes, a change of 6 in atomic number and 12 in atomic mass.

After this, the corresponding element becomes member of group 14 .

6. (d) According to Aufbau's principle, electrons are filled in increasing order of energy, so,

$^{26}Fe = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$

7. (b) Electronic configurations of-

Zn^+ (Z = 30) = $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$

Fe^{2+} (Z = 26) = $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^0$

N^{3+} (Z = 7) = $1s^2\ 2s^2\ 2p^0$

Cu^+ (Z = 29) = $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$

So, Fe^{2+} has maximum number of unpaired electrons.

8. (a) Atomic number of given element = 15, thus it belongs to 5^{th} group.

Now, atomic number of the element below the above element = 15 + 18 = 33

9. (c) Electronic configuration of an element is:

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^3$

Hence, it lies in fifth or 5^{th} group due to presence of five valence electrons.

10. (c) Elements a, b and d belong to the same group since each one of them has two electrons in valence shell. In contrast, element c, has seven electrons in the valence shell, and hence it lies in other group.

11. (d) Among isoelectronic monoatomic species, size is inversely proportional to atomic number.

Hence among isoelectronic species Na^+, O^{2-}, N^{3-}, F^- (having nearest noble gas configuration);

Order of size is $Na^+ < F^- < O^{2-} < N^{3-}$

N^{3-} has least atomic number hence largest size.

12. (c) Both (A) and (R) are correct and Reason is the correct explanation of Assertion.

13. (d) Species which contain same number of electrons are isoelectronic.

Ca^{+2}, Ar, K^+, $Cl^- \rightarrow$ 18 electrons.

14. (d) The nature of given oxides is given as:

NO → neutral CaO → Basic

CO_2 → Acidic ZnO → Atmospheric

15. (d) E. C. of C : → $1s^2, 2s^2, 2p^2$

E. C. of N : → $1s^2, 2s^2, 2p^3$ (more stable EC due to exactly half filled p-orbital)

E. C. of O : → $1s^2, 2s^2, 2p^4$

E. C. of F : → $1s^2, 2s^2, 2p^5$

∴ Order of first IE is C < O < N < F

16. (b) Given, $I.E_1$ of X < $I.E_1$ of Y

X- is alkali metal as it has large size, it's ionization energy is less.

After loss of one electron, it achieves inert gas configuration. Therefore, its IE_2 is very high.

Y is alkaline earth metal. It's ionization energy is more than that of alkali metal due to stable ns^2 configuration. But its IE_2 is lower than that of alkali metal.

17. (c) $Na^+ = 11 - 1 = 10\ e^-$

$Mg^{2+} = 12 - 2 = 10\ e^-$

Hence, isoelectronic pair.

$Mn^{2+} = 25 - 2 = 23\ e^-$

$Fe^{3+} = 26 - 3 = 23\ e^-$

Hence, isoelectronic pair.

$Fe^{2+} = 26 - 2 = 24\ e^-$

$Mn^{2+} = 25 - 2 = 23\ e^-$

Hence, not an isoelectronic pair.

$O^{2-} = 8 + 2 = 10\ e^-$

$F^- = 9 + 1 = 10\ e^-$

Hence, isoelectronic pair.

18. (b) 'Be' and 'N' have comparatively more stable valence sub-shell than 'B' and 'O'.

Generally, ionisation energies increases across a period and decreases down the group.

Thus, correct increasing order of first ionisation enthalpy is:

$Li < B < Be < C < O < N < F < Ne$

19. (c,d) Ionisation enthalpy increases across a period with an exception of Nitrogen atom's being higher than oxygen atom due to half filled orbital stability of N-atom.

Increasing first ionization enthalpy will be $B < C < O < N$.

Electron gain enthalpy decreases down the group, but due to electron-electron repulsions in F atom, its electron gain enthalpy is less than Cl atom.

$I < Br < F < Cl$

20. (d) There is a lot of repulsion when similar charges approach each other as $O^-(g)$ and e^- are both negatively charged. To add an electron under such situation, the force of repulsion is to be overcome by applying external energy.

21. (b) The atomic radius of an anion is more than that of neutral atom while in the case of a cation, the radius is less. Higher the positive charge on species, smaller will be the radius. So, the order given in option b is correct.

22. (a) $Be^{2+} = 2e^-$ $Li^+ = 2e^-$ $Na^+ = 10e^-$ $Mg^{2+} = 10e^-$ $H^+ = 0e^-$

Isoelectronic species means ions with same number of electrons.

23. (b) Cations lose electrons and are smaller in size than the parent atom, whereas anions add electrons and are larger in size than the parent atom.

Hence, the order is $H^- > H > H^+$.

For isoelectronic species, the ionic radii decreases with increase in atomic number i.e., nuclear charge.

Hence, the correct orders are:

$O^{2-} > F^- > Na^+$ and $N^{3-} > Mg^{2+} > Al^{3+}$

24. (b) Among isoelectronic species, the ion with the maximum positive charge will have the smallest radius because of greater effective nuclear charge.

25. (c) Electron gain enthalpy is reverse of ionization energy. So if ionization energy of $Na^+ = 5.1eV$ then, electron gain enthalpy will be -5.1 eV.

26. (b) The order of increasing atomic radii is $Ca > Mg > P > Cl$. As we go down the group, size increases & on moving left to right in a period, size decreases.

27. (c) As the atomic number increases from group 16 to 17, the electron gain enthalpy becomes more negative, also, it is the highest for group 17 members followed by group 16.

Group 17 $\rightarrow$ $Cl > F > Br > I$

Group 16 $\rightarrow$ $S > Se > Te > Po > O$

28. (d) $S^{2-} > Cl^- > K^+ > Ca^{2+}$

More the negative charge over an ion increases, effective nuclear Z_{eff} charge decreases & thus the ionic radii increases, with increase in positive charge, Z_{eff} increases & ionic radii decrease.

29. (d) Highest ionisation energy will be of [Ne] $3s^23p^3$, it has half-filled 3p orbitals which are most stable than partially filled orbitals.

$\therefore$ It will be very difficult to extract electron from a stable system.

30. (b) The factors on which the ionization energy depends are:

(i) **Atomic size** – Ionization enthalpy decreases as the atomic size increases. So, the attractive nuclear force decreases.

(ii) **Number of electrons in the inner shell** (screening effect) – As the number of shells increases, screening effect also increases and hence, the ionisation enthalpy tends to decrease.

31. (a) For isoelectronic species, size of anion increases as negative charge increases whereas size of cation decreases with increase in positive charge. Further ionic radii of anions is more than that of cations. Also, neutral atom is always smaller than anion and larger than cation. Thus, the correct order is:

$Ca^{2+} < K^+ < Ar < Cl^- < S^{2-}$

32. (b) In a group, electron gain enthalpy decreases down the group. But due to electron-electron repulsions in O and F atom, their electron gain enthalpy is less than S and Cl atoms respectively. Thus, order becomes $O < S < F < Cl$

33. (d) Ionic radii are inversely proportional to effective nuclear charge.

$$r_n \propto \frac{1}{z^*}$$

Where z* is the effective nuclear charge.

34. (b) Amongst isoelectronic ions, ionic radii of anions is more than that of cations. Further size of anion increases with increase in –ve charge & size of cation decreases with increase in +ve charge. Hence, correct order is:

$O^{2-} > F^- > Na^+ > Mg^{2+} > Al^{3+}$

35. (b) Li, Be, B, C - these elements belong to the same period. Generally the value of first ionisation potential increases while moving from left to right in a period, since the nuclear charge of the elements also increase in the same direction. But the ionisation potential of B ($B \rightarrow 2s^2 2p^1$) is lower than that of Be ($Be \rightarrow 2s^2$), because in case of boron, $2p^1$ electron has to be removed to get B^+ while in case of Be ($2s^2$), s-electron has to be removed to get Be^+ ($2s^1$). p-electron can be removed more easily than that of s-electron, therefore the energy required to remove electron will be less in case of boron. Hence, the order will be:

$Li < B < Be < C$.

36. (a) The energy required to remove the most loosely bound electron from an isolated gaseous atom is called the ionisation energy. The ionisation potential increases as the size of the atom decreases. Atom with fully or partly filled orbitals have high ionisation potential. Since Be has fully filled $2s^2$ orbital, therefore it has higher ionisation potential than B.

Similarly, nitrogen has half filled orbitals, therefore, its ionisation energy will be higher than oxygen.

37. (a) Due to more repulsion between non-bonding electron pair (2p) of two fluorines (due to small size of F-atom) in comparison to non-bonding electron pair (3p) in chlorine, the bond energy of F_2 is less than Cl_2.

B.E. (F_2) = 158.5 kJ/mole and

B.E. (Cl_2) = 242.6 kJ/mole

38. (c) Electron affinity value of 'F' should be maximum but due to exceptionally small size and 7 electron in its valence shell, there is high electron-electron repulsion.

$\therefore$ Thus, the order becomes I < Br < F < Cl

39. (d) First ionisation potential of Be (completely filled orbitals) is greater than boron due to stable configuration

Be ($Z = 4$) = $1s^2\ 2s^2$

B($Z = 5$) = $1s^2\ 2s^2\ 2p^1$

Order of attraction of electrons towards nucleus 2s > 2p, so more amount of energy is required to remove the electrons with 2s orbitals in comparison to 2p orbitals. So ionisation potential of Be is 9.32 eV and B is 8.29 eV.

40. (b) Positive ion is always smaller and negative ion is always larger than the parent atom. So, the correct order is given in option (b).

41. (d) Since all of these ions contain 18 electrons each, so these are isoelectronic. For isoelectronic ions, smaller the positive nuclear charge, greater is the size of the ion.

42. (a) These are isoelectronic ions (ions with same number of electrons) and for isoelectronic ions, greater the positive nuclear charge, greater is the force of attraction on the electrons by the nucleus and the smaller is the size of the ion. Thus, Al^{3+} has the smallest size.

43. (c) In isoelectronic ions, the size of the cation decreases as the magnitude of the positive charge increases and the size of anion increases as the magnitude of negative charge increases.

44. (d) Atomic volume is the volume occupied by one gram of an element. Within a period from left to right, atomic volume first decreases and then increases.

45. (d) Non-metal like halogens are strongest oxidizing agents according to electrochemical series. They form acidic oxides, they from anion by electron gain and they are highly electronegative.

46. (d) In (d) after removing second valence electron from 3s orbital, the ion will attain stable noble gas configuration. So, to remove the third electron from 2p, a large amount of energy will be required. Hence, there is an abnormally high difference between second and third ionization enthalpy.

$$1s^2\ 2s^2\ 2p^6\ 3s^2 \xrightarrow{+E_1} 1s^2\ 2s^2\ 2p^6\ 3s^1 \xrightarrow{+IE_2} 1s^2\ 2s^2\ 2p^6$$
$$\xrightarrow{+IE_3} 1s^2\ 2s^2\ 2p^5$$

47. (a) Pauling introduced the electronegativity concept. He introduced the idea that the ionic character of a bond varies with the difference in electronegativity. A large difference in electronegativity leads to a bond with high degree of polar character, i.e. the bond is predominantly ionic or vice versa.

48. (a) Metallic character decreases in a period and increases in a group because down the group, as the size increases, tendency to lose electrons increases.

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CHAPTER 4

Chemical Bonding and Molecular Structure

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Covalent Bond, Electrovalent Bond, Lattice Enthalpy and Octet Rule

1. Amongst the following, the total number of species NOT having eight electrons around central atom in its outer most shell, is: NH_3, $AlCl_3$, $BeCl_2$, CCl_4, PCl_5 [MR*] *(2023)*

a. 1 b. 3
c. 2 d. 4

2. Which of the following species contains equal number of σ and π-bonds? [MR*] *(2015 Re)*

a. $(CN)_2$ b. $(CH)_2(CN)_2$
c. HCO_3 d. XeO_4

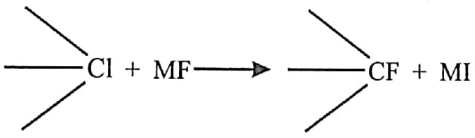
3. Which one of the following molecules contains no π bond? *(2013)*

a. SO_2 b. NO_2
c. CO_2 d. H_2O

4. Which of the following is electron-deficient? *(2013)*

a. $(CH_3)_2$ b. $(SiH_3)_2$
c. $(BH_3)_2$ d. PH_3

5. In the replacement reaction



The reaction will be most favorable if M happens to be: *(2012 Mains)*

a. Li b. Na
c. K d. Rb

6. Which of the following compounds has the lowest melting point? *(2011 Pre)*

a. CaF_2 b. $CaCl_2$
c. $CaBr_2$ d. CaI_2

7. Among the following which one has the highest cation to anion size ratio? [MR*] *(2010 Mains)*

a. CsI b. CsF
c. LiF d. NaF

8. The sequence of ionic mobility in aqueous solution is: [MR*] *(2008)*

a. $Na^+ > K^+ > Rb^+ > Cs^+$ b. $K^+ > Na^+ > Rb^+ > Cs^+$
c. $Cs^+ > Rb^+ > K^+ > Na^+$ d. $Rb^+ > K^+ > Cs^+ > Na^+$

9. The table shown below gives the bond dissociation energies (E_{diss}) for single covalent bonds of carbon atoms with element A, B, C and D. Which element has the smallest atoms? *(1994)*

Bond	E_{diss} (kJ mol^{-1})
C–A	240
C–B	328
C–C	276
C–D	485

a. C b. D
c. A d. B

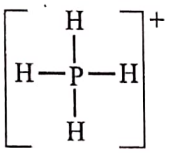
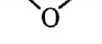
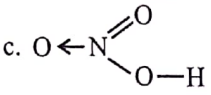
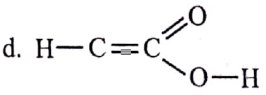
10. Among the following, which compound will show the highest lattice energy? *(1993)*

a. KF b. NaF
c. CsF d. RbF

11. Which one of the following is the correct order of interactions' *(1993)*

a. Covalent < hydrogen bonding < Van Der Waals' < dipole dipole
b. Van Der Waals' < hydrogen bonding < dipole < covalen
c. Van Der Waals' < dipole-dipole < hydrogen bonding covalent
d. Dipole-dipole < Van Der Waals' < hydrogen bonding covalent.

12. Which one of the following formulae does not correctly represe the bonding capacities of the two atoms involved? *(199*

a. 
b. 
c. 
d. 

13. Which of the following does not apply to metallic bon *(198*

a. Overlapping valence orbitals
b. Mobile valence electrons
c. Delocalized electrons
d. Highly directed bonds

Bond Parameters and Dipole Moment

14. The correct order of dipole moments for molecules NH_3, H_2S, CH_4 and HF, is: *(2023-Manipur)*

a. $CH_4 > H_2S > NH_3 > HF$

b. $H_2S > NH_3 > HF > CH_4$

c. $NH_3 > HF > CH_4 > H_2S$

d. $HF > NH_3 > H_2S > CH_4$

15. The correct order of bond angles in the following compounds/ species is: [**MR***] *(2022 Re)*

a. $CO_2 < NH_3 < H_2O < \overset{+}{N}H_4$

b. $H_2O < NH_3 < \overset{+}{N}H_4 < CO_2$

c. $H_2O < \overset{+}{N}H_4 < NH_3 < CO_2$

d. $H_2O < \overset{+}{N}H_4 = NH_3 < CO_2$

16. Which of the following molecules is non-polar in nature? *(2021)*

a. CH_2O b. $SbCl_5$

c. NO_2 d. $POCl_3$

17. Which of the following set of molecules will have zero dipole moment? [**MR***] *(2020)*

a. Boron trifluoride, hydrogen fluoride, carbon dioxide, 1, 3-dichlorobenzene

b. Nitrogen trifluoride, beryllium difluoride, water 1, 3-dichlorobenzzene

c. Boron trifluoride, beryllium difluoride, carbon dioxide, 1,4-dichlorobenzene

d. Ammonia, beryllium difluoride, water, 1, 4-dichlorobenzene

18. Which one of the following pair of species have the same bond order? [**MR***] *(2017-Delhi)*

a. N_2, O_2^- b. CO, NO

c. O_2, NO^+ d. CN^-, CO

19. Consider the molecules CH_4, NH_3 and H_2O. Which of the given statement is false? *(2016 - I)*

a. The H—C—H bond angle in CH_4 is larger than the H—N—H bond angle in NH_3

b. The H—C—H bond angle in CH_4, the H—N—H bond angle in NH_3, and the H—O—H bond angle in H_2O are all greater than 90°.

c. Then H—O—H bond angle in H_2O is larger than the H—C—H bond angle in CH_4

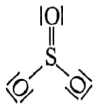
d. The H—O—H bond angle in H_2O is smaller than the H—N—H bond angle in NH_3

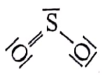
20. Which of the following molecules has the maximum dipole moment? *(2014)*

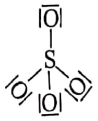
a. CH_4 b. NH_3

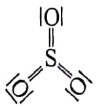
c. NF_3 d. CO_2

21. Which of the following structures is the most preferred and hence of lowest energy for SO_3? *(2011 Mains)*

a. 

b. 

c. 

d. 

22. The correct order of increasing bond length of C—H, C—O, C—C and C=C is: [**MR***] *(2011 Pre)*

a. C—H < C—O < C—C < C=C

b. C—H < C=C < C—O < C—C

c. C—C < C=C < C—O < C—H

d. C—O < C—H < C—C < C=C

23. The correct order of increasing bond angles in the following species is: *(2010 Pre)*

a. $Cl_2O < ClO_2 < ClO_2^-$ b. $ClO_2 < Cl_2O < ClO_2^-$

c. $Cl_2O < ClO_2^- < ClO_2$ d. $ClO_2^- < Cl_2O < ClO_2$

24. In the case of alkali metals, the covalent character decreases in the order: *(2009)*

a. MF > MCl > MBr > MI b. MF > MCl > MI > MBr

c. MI > MBr > MCl > MF d. MCl > MI > MBr > MF

25. The correct order of increasing bond angles in the following triatomic species is: *(2008)*

a. $NO_2^+ < NO_2^- < NO_2$ b. $NO_2^- < NO_2^+ < NO_2$

c. $NO_2^- < NO_2 < NO_2^+$ d. $NO_2^+ < NO_2 < NO_2^-$

26. The correct order of C–O bond length among: CO, CO_3^{2-}, CO_2 is: *(2007)*

a. $CO < CO_3^{2-} < CO_2$ b. $CO_3^{2-} < CO_2 < CO$

c. $CO < CO_2 < CO_3^{2-}$ d. $CO_2 < CO_3^{2-} < CO$

27. The electronegativity difference between N and F is greater than that between N and H yet the dipole moment of NH_3 (1.5 D) is larger than that of NF_3 (0.2 D). This is because: *(2006)*

a. In NH_3 as well as in NF_3, the atomic dipole and bond dipole are in the same direction

b. In NH_3, the atomic dipole and bond dipole are in the same direction whereas in NF_3 these are in opposite directions

c. In NH_3, as well as NF_3 the atomic dipole and bond dipole are in opposite directions

d. In NH_3, the atomic dipole and bond dipole are in the opposite directions whereas, in NF_3 these are in the same directions

28. The correct sequence of increasing covalent character is represented by: *(2005)*

a. LiCl < NaCl < $BeCl_2$ b. $BeCl_2$ < NaCl < LiCl

c. NaCl < LiCl < $BeCl_2$ d. $BeCl_2$ < LiCl < NaCl

29. Which of the following would have a permanent dipole moment? *(2005)*

a. BF_3 b. SiF_4

c. SF_4 d. XeF_4

30. The correct order in which the O—O bond length increases in the following is: *(2005)*

a. $H_2O_2 < O_2 < O_3$ b. $O_3 < H_2O_2 < O_2$
c. $O_2 < O_3 < H_2O_2$ d. $O_2 < H_2O_2 < O_3$

31. H_2O is dipolar, whereas BeF_2 is not. It is because *(2004)*

a. H_2O involves hydrogen bonding whereas BeF_2 is a discrete molecule
b. H_2O is linear and BeF_2 is angular
c. H_2O is angular and BeF_2 is linear
d. The electronegativity of F is greater than that of O

32. Which of the following statements is not correct for sigma- and pi-bonds formed between two carbon atoms? *(2003)*

a. Sigma-bond is stronger than a pi-bond
b. Bond energies of sigma- and pi-bonds are of the order of 264 kJ/mol and 347 kJ/mol, respectively
c. Free rotation of atoms about a sigma bond is allowed but not in case of a pi-bond
d. Sigma-bond determines the direction between carbon atoms but a pi-bond has no primary effect in this regard

33. In PO_4^{3-} ion, the formal charge on each oxygen atom and P-O bond order respectively are: *(1998)*

a. –0.75, 0.6 b. –0.75, 1.0
c. –0.75, 1.25 d. –3, 1.25

34. The bond length between hybridized carbon atom and other carbon atom is minimum in *(1996)*

a. Propene b. Propyne
c. Propane d. Butane

35. The correct order of the O – O bond length in O_2, H_2O_2 and O_3 is: *(1995)*

a. $O_2 > H_2O_2 > O_3$ b. $H_2O_2 > O_3 > O_2$
c. $O_2 > O_3 > H_2O_2$ d. $O_3 > H_2O_2 > O_2$

36. Which of the following molecule does not possess a permanent dipole moment? *(1994)*

a. CS_2 b. SO_3
c. H_2S d. SO_2

37. Which one of the following has the shortest carbon carbon bond length? *(1992)*

a. Benzene b. Ethene
c. Ethyne d. Ethane

38. In compound *X*, all the bond angles are exactly 109°28′, *X* is: *(1991)*

a. Chloromethane b. Carbon tetrachloride
c. Iodoform d. Chloroform

39. Among LiCl, $BeCl_2$, BCl_3 and CCl_4, the covalent bond character follows the order: **[MR*]** *(1990)*

a. $BeCl_2 > BCl_3 > CCl_4 < LiCl$
b. $BeCl_2 < BCl_3 < CCl_4 < LiCl$
c. $LiCl < BeCl_2 < BCl_3 < CCl_4$
d. $LiCl > BeCl_2 > BCl_3 > CCl_4$

40. H_2O has a net dipole moment while BeF_2 has zero dipole moment because: *(1989)*

a. H_2O molecule is linear while BeF_2 is bent
b. BeF_2 molecule is linear while H_2O is bent
c. Fluorine has more electronegativity than oxygen
d. Beryllium has more electronegativity than oxygen

VSEPR Theory

41. Match List - I with List - II: *(2022 Re)*

	List-I (molecules)		List-II (shape)
A.	NH_3	I.	square pyramidal
B.	ClF_3	II.	trigonal bipyramidal
C.	PCl_5	III.	trigonal pyramidal
D.	BrF_5	IV.	T-shape

Choose the **correct answer** from the options given below:

a. A-III, B-IV, C-I, D-II b. A-II, B-III, C-IV, D-I
c. A-III, B-IV, C-II, D-I d. A-IV, B-III, C-I, D-II

42. Amongst the following, which one will have maximum 'lone pair-lone pair' electron repulsions? **[MR*]** *(2022)*

a. XeF_2 b. ClF_3
c. IF_5 d. SF_4

43. Match List-I with List-II.

List-I		List-II	
(A)	PCl_5	(i)	Square pyramidal
(B)	SF_6	(ii)	Trigonal planar
(C)	BrF_5	(iii)	Octahedral
(D)	BF_3	(iv)	Trigonal bipyramidal

Choose the correct answer from the options given below. **[MR*]** *(2021)*

a. A-ii B-iii C-iv D-i
b. A-iii B-i C-iv D-ii
c. A-iv B-iii C-ii D-i
d. A-iv B-iii C-i D-ii

44. Identify the wrongly matched pair. *(2020-Covid)*

	Molecule	Shape or geometry of molecule
a.	SF_6	Octahedral
b.	$BeCl_2$	Linear
c.	NH_3	Trigonal pyramidal
d.	PCl_5	Trigonal planar

45. Identify the incorrect statement related to PCl_5 from the following: *(2019)*

a. Three equatorial P-Cl bonds make an angle of 120° with each other
b. Two axial P-Cl bonds make an angle of 180° with each other
c. Axial P-Cl bonds are longer than equatorial P-Cl bonds
d. PCl_5 molecule is non-reactive

46. The species, having bond angles of 120° is *(2017-Delhi)*
a. BCl_3 b. PH_3
c. ClF_3 d. NCl_3

47. Among the following which one is a wrong statement? [MR*] *(2016 - II)*
a. SeF_4 and CH_4 have same shape
b. I_3^+ has bent geometry
c. PH_5 and $BiCl_5$ do not exist
d. $p\pi - d\pi$ bonds are present in SO_2

48. Which of the following pairs of ions is isoelectronic and isostructural? *(2016-II)*
a. CO_3^{2-}, NO_3^- b. ClO_3^-, CO_3^{2-}
c. SO_3^{2-}, NO_3^- d. ClO_3^-, SO_3^{2-}

49. Predict the correct order among the following: *(2016 - I)*
a. Lone pair – bond pair > bond pair – bond pair > lone pair – lone pair
b. Lone pair – lone pair > lone pair – bond pair > bond pair – bond pair
c. Lone pair – lone pair > bond pair – bond pair > lone pair – bond pair
d. Bond pair – bond pair > lone pair – bond pair > lone pair – lone pair

50. Maximum bond angle at nitrogen is present in which of the following? *(2015)*
a. NO_2^+ b. NO_3^-
c. NO_2 d. NO_2^-

51. In which of the following pairs, both the species are not isostructural? *(2015)*
a. Diamond, Silicon carbide
b. NH_3, PH_3
c. XeF_4, XeO_4
d. $SiCl_4$, PCl_4^+

52. Which of the following pairs of ions are isoelectronic and isostructural? [MR*] *(2015)*
a. SO_3^{2-}, NO_3^- b. ClO_3^-, SO_3^{2-}
c. CO_3^{2-}, SO_3^{2-} d. ClO_3^-, CO_3^{2-}

53. Which one of the following species has planar triangular shape? *(2014)*
a. NO_3^- b. NO_2^-
c. CO_2 d. N_3^-

54. Which of the following is a polar molecule? *(2013)*
a. BF_3 b. SF_4
c. SiF_4 d. XeF_4

55. XeF_2 is isostructural with *(2013)*
a. $SbCl_3$ b. $BaCl_2$
c. TeF_2 d. ICl_2^-

56. Which one of the following pairs is iso-structural (i.e., having the same shape and hybridization)? *(2012 Pre)*
a. [BF_4^- and NH_4^+] b. [BCl_3 and $BaCl_2$]
c. [NH_3 and NO_3^-] d. [NF_3 and BF_3]

57. Which of the following species contains three bond pairs and one lone pair around the central atom? *(2012)*
a. H_2O b. BF_3
c. NH_2^- d. PCl_3

58. The angular shape of molecule (O_3) consists of: *(2008)*
a. 2 sigma and 1 pi bond b. 1 sigma and 2 pi bonds
c. 2 sigma and 2 pi bonds d. 1 sigma and 1 pi bond

59. In which of the following pairs, the two species are iso-structural? *(2007)*
a. SO_3^{2-} and NO_3^- b. BF_3 and NF_3
c. BrO_3^- and XeO_3 d. SF_4 and XeF_4

60. In which of the following molecules, all the bonds are not equal? *(2006)*
a. NF_3 b. ClF_3
c. BF_3 d. AlF_3

61. Which of the following is not iso-structural with $SiCl_4$? *(2006)*
a. SCl_4 b. SO_4^{2-}
c. PO_4^{3-} d. NH_4^-

62. Which of the following is not a correct statement? *(2006)*
a. The electron-deficient molecules can act as Lewis acids
b. The canonical structures have no real existence
c. Every AB_5 molecule does in fact have square pyramid structure
d. Multiple bonds are always shorter than corresponding single bonds

63. Which of the following species has a linear shape? *(2006)*
a. NO_2^- b. SO_2
c. NO_2^+ d. O_3

64. Which of the following molecules has trigonal planar geometry? *(2005)*
a. IF_3 b. PCl_3
c. NH_3 d. BF_3

65. Among the following, the pair in which the two species are not isostructural is: *(2004)*
a. IO_3^- and XeO_3 b. BH_4^- and NH_4^+
c. PF_6^- and SF_6 d. SiF_4 and SF_4

66. In a regular octahedral molecule, MX_6 the number of X–M–X bonds at 180° is: *(2004)*
a. Two b. Six
c. Four d. Three

67. In BrF_3 molecule, the lone pairs occupy equatorial positions to minimize: [MR*] *(2004)*
a. Bond pair-bond pair repulsion only
b. Lone pair-lone pair repulsion and lone pair-bond pair repulsion
c. Lone pair-lone pair repulsion only
d. Lone pair-bond pair repulsion only

68. In NO_3^- ion, number of bond pair and lone pair of electrons on nitrogen atom are: *(2002)*
a. 2, 2 b. 3, 1
c. 1, 3 d. 4, 0

69. Which of the following is iso-electronic? *(2002)*

a. CO_2, NO_2 b. NO_2^-, CO_2
c. CN^-, CO d. SO_2, CO_2

70. In which of the following, bond angle is maximum? [MR*] *(2001)*

a. NH_3 b. NH_4^+
c. PCl_3 d. SCl_2

71. Which of the following two species in the pair are isostructural? *(2001)*

a. XeF_2, IF_2^- b. NH_3, BF_3
c. CO_3^{2-}, SO_3^{2-} d. PCl_5, ICl_5

72. BCl_3 is a planar molecule whereas NCl_3 is pyramidal because: *(1995)*

a. Nitrogen atom is smaller than boron atom
b. BCl_3 has no lone pair but NCl_3 has a lone pair of electrons
c. B-Cl bond is more polar than N-Cl bond
d. N-Cl bond is more covalent than B-Cl bond

73. Which structure is linear? *(1992)*

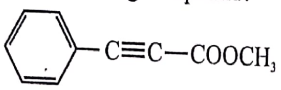
a. SO_2 b. CO_2
c. CO_3^{2-} d. SO_4^{2-}

Valence Bond Theory, Hybridisation

74. BF_3 is planar and electron deficient compound. Hybridization and number of electrons around the central atom, respectively are: *(2021)*

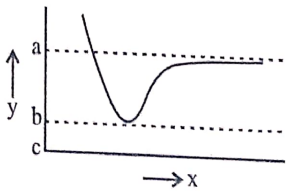
a. sp^3 and 6 b. sp^2 and 6
c. sp^2 and 8 d. sp^3 and 4

75. How many (i) sp^2 hybridised carbon atoms and (ii) π bonds are present in the following compound? *(2020-Covid)*



a. 8, 6 b. 7, 6
c. 8, 5 d. 7, 5

76. The potential energy (y) curve for H_2 formation as a function of internuclear distance (x) of the H atoms is shown below. *(2020-Covid)*



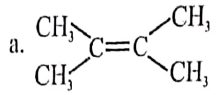
The bond energy of H_2 is

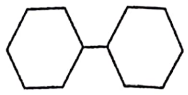
a. $\frac{(c-a)}{2}$ b. $\frac{(b-a)}{2}$
c. $(c-a)$ d. $(b-a)$

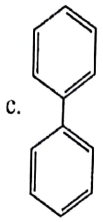
77. The hybridisation of atomic orbitals of nitrogen in NO_2^+, NO_3^- and NH_4^+ respectively are: [MR*] *(2016-II)*

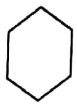
a. *sp*, sp^3 and sp^2 b. sp^2, sp^3 and *sp*
c. *sp*, sp^2 and sp^3 d. sp^2, *sp* and sp^3

78. In which of the following molecules, all atoms are coplanar? *(2016-II)*

a. 

b. 

c. 

d. 

79. The correct geometry and hybridization for XeF_4 are *(2016-II)*

a. Octahedral, sp^3d^2 b. Trigonal bipyramidal, sp^3d
c. Planar triangle, sp^3d^3 d. Square planar, sp^3d^2

80. Which of the following organic compounds has same hybridisation as its combustion product (CO_2)? *(2014)*

a. Ethyne b. Ethene
c. Ethanol d. Ethane

81. Considering the state of hybridisation of carbon atoms, find out the molecule among the following which is linear? *(2011 Prev)*

a. $CH_3 — CH_2 — CH_2 — CH_3$
b. $CH_3 — CH = CH — CH_3$
c. $CH_3 — C \equiv C — CH_3$
d. $CH_2 = CH — CH_2 — C \equiv CH$

82. Which of the two ions from the list given below have the geometry that is explained by the same hybridisation of orbitals?

NO_2^+, NO_3^-, NH_2^-, NH_4^+, SCN^- [MR*] *(2011 Prev)*

a. NO_2^+ and NH_2^- b. NO_2^+ and NO_3^-
c. NH_4^+ and NO_3^- d. SCN^- and NH_2^-

83. Some of the properties of the two species, NO_3^- and H_3O^+ are described below. Which one of them is correct? *(2010 Mains)*

a. Dissimilar in hybridisation for the central atom with different structures
b. Isostructural with same hybridisation for the central atom
c. Isostructural with different hybridisation for the central atom
d. Similar in hybridisation for the central atom with different structures

84. In which of the following molecules, the central atom does not have sp^3 hybridisation? *(2010 Mains)*

a. CH_4 b. SF_4
c. BF_4^- d. NH_4^+

85. In which one of the following species, the central atom has the type of hybridisation which is not the same as that present in the other three? *(2010 Prev)*

a. PCl_5 b. SF_4
c. I_3^- d. $SbCl_5^{2-}$

86. In which of the following pairs of molecules/ions, the central atoms have sp^2 hybridisation? *(2010 Pre)*

a. NH_2^- and H_2O b. NO_2^- and H_2O

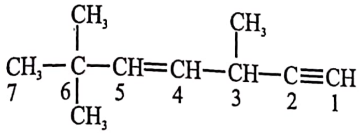
c. BF_3 and NO_2^- d. NO_2^- and NH_2^-

87. In which of the following molecules/ions BF_3, NO_2^-, NH_2^- and H_2O, the central atom is sp^2 hybridised? *(2009)*

a. NH_2^- and H_2O b. NO_2^- and H_2O

c. BF_3 and NO_2^- d. NO_2^- and NH_2^-

88. The state of hybridisation of C_2, C_3, C_5 and C_6 of the hydrocarbon,



is in the following sequence: *(2009)*

a. sp^3, sp^2, sp^2 and sp b. sp, sp^2, sp^2 and sp^3

c. sp, sp^2, sp^3 and sp^2 d. sp, sp^3, sp^2 and sp^3

89. The correct order regarding the electronegativity of hybrid orbitals of carbon is: [**MR***] *(2006)*

a. $sp > sp^2 < sp^3$ b. $sp > sp^2 > sp^3$

c. $sp < sp^2 > sp^3$ d. $sp < sp^2 < sp^3$

90. Which of the following has $p\pi$-$d\pi$ bonding? *(2002)*

a. NO_3^- b. SO_3^{2-}

c. BO_3^{3-} d. CO_3^{2-}

91. Nitrogen form N_2, but phosphorous form P_2, but after some time convert in P_4, reason is: *(2001)*

a. Triple bond present between phosphorous atom

b. $p\pi - p\pi$ bonding is weak

c. $p\pi - p\pi$ binding is strong

d. Multiple bond form easily

92. $d\pi - p\pi$ bond is present in: *(2000)*

a. CO_3^{2-} b. PO_4^{3-}

c. NO_3^- d. NO_2^-

93. The structure and hybridisation of $Si(CH_3)_4$ is: *(1996)*

a. Octahedral, sp^3d b. Tetrahedral, sp^3

c. Bent, sp d. Trigonal, sp^2

94. Which of the following has sp^2 hybridisation? *(1996)*

a. $BeCl_2$ b. C_2H_2

c. C_2H_6 d. C_2H_4

95. The complex ion $[Co(NH_3)_6]^{3+}$ is formed by sp^3d^2 hybridisation. Hence the ion should possess: *(1990)*

a. Octahedral geometry b. Tetrahedral geometry

c. Square planar geometry d. Tetragonal geometry.

96. Which statement is NOT correct? [**MR***] *(1990)*

a. A sigma bond is weaker than a pi bond.

b. A sigma bond is stronger than a pi bond.

c. A double bond is stronger than a single bond.

d. A double bond is shorter than a single bond.

97. Linear combination of two hybridised orbitals belonging to two atoms and each having one electron leads to the formation of: *(1990)*

a. Sigma bond

b. Double bond

c. Co-ordinate covalent bond

d. Pi bond

98. Which of the following molecule does not have a linear arrangement of atoms? *(1989)*

a. H_2S b. C_2H_2

c. BeH_2 d. CO_2

99. In which one of the following molecules, the central atom can be said to adopt sp^2 hybridisation? *(1989)*

a. BeF_2 b. BF_3

c. C_2H_2 d. NH_3

100. The angle between the overlapping of one *s*-orbital and one *p*-orbital is: *(1988)*

a. 180° b. 120°

c. 109.28° d. 120°– 60°

101. Equilateral shape has: *(1988)*

a. sp hybridisation b. sp^2 hybridisation

c. sp^3 hybridisation d. dsp^3 hybridisation.

MOT, Bonding in Some Homonuclear Diatomic Molecules

102. The correct order of energies of molecular orbitals of N_2 molecule is: [**MR***] *(2023)*

a. $\sigma 1s < \sigma^* 1s < \sigma 2s < \sigma^* 2s < (\pi 2p_x = \pi 2p_y) < (\pi^* 2p_x = \pi^* 2p_y) < \sigma 2p_z < \sigma^* 2p_z$

b. $\sigma 1s < \sigma^* 1s < \sigma 2s < \sigma^* 2s < (\pi 2p_x = \pi 2p_y) < \sigma 2p_z < (\pi^* 2p_x = \pi^* 2p_y) < \sigma^* 2p_z$

c. $\sigma 1s < \sigma^* 1s < \sigma 2s < \sigma^* 2s < \sigma 2p_z < (\pi 2p_x = \pi 2p_y) < (\pi^* 2p_x = \pi^* 2p_y) < \sigma^* 2p_z$

d. $\sigma 1s < \sigma^* 1s < \sigma 2s < \sigma^* 2s < \sigma 2p_z < \sigma^* 2p_z < (\pi 2p_x = \pi 2p_y) < (\pi^* 2p_x = \pi^* 2p_y)$

103. Which one of the following statements is **incorrect** related to Molecular Orbital Theory? *(2023-Manipur)*

a. The p^* antibonding molecular orbital has a node between the nuclei.

b. In the formation of bonding molecular orbital, the two election waves of the bonding atoms reinforce each other.

c. Molecular orbitals obtained from $2P_x$ and $2P_y$ orbitals are symmetrical around the bond axis.

d. A p-bonding molecular orbital has lager electron density above and below the internuclear axis.

104. Which amongst the following is incorrect statement [MR*] *(2022)*

a. O^+_2 ion is diamagnetic.
b. The bond orders of O^+_2, O_2, O^-_2 and O^{2-}_2 are 2.5, 2, 1.5 and 1, respectively
c. C_2 molecule has four electrons in its two degenerate π molecular orbitals.
d. H^+_2 ion has one electron.

105. Identify a molecule which does not exist. *(2020)*

a. Li_2 b. C_2
c. O_2 d. He_2

106. Which of the following diatomic molecular species has only π bonds according to Molecular Orbital Theory? *(2019)*

a. O_2 b. N_2
c. C_2 d. Be_2

107. Consider the following species: *(2018)*

CN^+, CN^-, NO and CN

Which one of these will have the highest bond order?

a. NO b. CN^-
c. CN d. CN^+

108. Decreasing order of stability of O_2, O^-_2, O^+_2 and O^{2-}_2 is: *(2015 Re)*

a. $O^-_2 > O^{2-}_2 > O^+_2 > O_2$ b. $O^+_2 > O_2 > O^-_2 > O^{2-}_2$
c. $O^{2-}_2 > O^-_2 > O_2 > O^+_2$ d. $O_2 > O^+_2 > O^{2-}_2 > O^-_2$

109. Which of the following options represents the correct bond order? *(2015)*

a. $O^-_2 < O_2 < O^+_2$ b. $O^-_2 > O_2 < O^+_2$
c. $O^-_2 < O_2 > O^+_2$ d. $O^-_2 > O_2 > O^+_2$

110. The correct bond order in the following species is: *(2015)*

a. $O^{2+}_2 < O^-_2 < O^+_2$ b. $O^{2+}_2 < O^-_2 < O^+_2$
c. $O^-_2 < O^+_2 < O^{2+}_2$ d. $O^{2+}_2 < O^+_2 < O^-_2$

111. Which of the following is paramagnetic? *(2013)*

a. CO b. O^-_2
c. CN^- d. NO^+

112. Four diatomic species are listed below. Identify the correct order in which the bond order is increasing in them: [MR*] *(2012 Mains)*

a. $He^+_2 < O^-_2 < NO < C^{2-}_2$ b. $NO < O^-_2 < C^{2-}_2 < He^+_2$
c. $O^-_2 < NO < C^{2-}_2 < He^+_2$ d. $C^{2-}_2 < He_2{}^+ < O^-_2 < NO$

113. During change of O_2 to O^-_2 ion, the electron adds on which one of the following orbitals? *(2012 Mains)*

a. π* orbital b. π orbital
c. σ* orbital d. σ orbital

114. The pair of species with the same bond order is: *(2012 Pre)*

a. N_2, O_2 b. O^{2-}_2, B_2
c. O^+_2, NO^+ d. NO, CO

115. Bond order of 1.5 is shown by: *(2012 Pre)*

a. O_2 b. O^+_2
c. O^-_2 d. O^{2-}_2

116. The pair of species of oxygen and their magnetic behaviours are noted below. Which of the following given represents the correct description? *(2011 Mains)*

a. O^+_2, O_2 – Both paramagnetic
b. O, O^{2-}_2 – Both paramagnetic
c. O^-_2, O^{2-}_2 – Both diamagnetic
d. O^+, O^{2-}_2 – Both paramagnetic

117. Which of the following has the minimum bond length? *(2011 Pre)*

a. O_2 b. O^+_2
c. O^-_2 d. O^{2-}_2

118. Which one of the following species does not exist under normal conditions? *(2010 Pre)*

a. Li_2 b. Be^+_2
c. Be_2 d. B_2

119. According to MO theory, which of the following lists ranks the nitrogen species in terms of increasing bond order? *(2009)*

a. $N^{2-}_2 < N^-_2 < N_2$ b. $N_2 < N^{2-}_2 < N^-_2$
c. $N^-_2 < N^{2-}_2 < N_2$ d. $N^-_2 < N_2 < N^{2-}_2$

120. Four diatomic species are listed below in different sequences. Which of these presents the correct order of their increasing bond order? [MR*] *(2008)*

a. $He^+_2 < O^-_2 < NO < C^{2-}_2$ b. $O^+_2 < NO < C^{2-}_2 < He^+_2$
c. $NO < C^{2-}_2 < O^-_2 < He^+_2$ d. $C^{2-}_2 < He^+_2 < NO < O^-_2$

121. The number of unpaired electrons in a paramagnetic diatomic molecule of an element with atomic number 16 is: *(2006)*

a. 2 b. 3
c. 4 d. 1

122. Which one of the following oxides is expected to exhibit paramagnetic behaviour? *(2005)*

a. CO_2 b. SO_2
c. ClO_2 d. SiO_2

123. Main axis of a diatomic molecule is *z*, molecular orbital p_x and p_y overlaps to form, which of the following orbital? *(2001)*

a. π molecular orbital b. σ molecular orbital
c. δ molecular orbital d. No bond will form

124. Which species does not exhibits paramagnetism? *(2000)*

a. N^+_2 b. O^-_2
c. CO d. NO

125. Correct order of dissociation energy of N_2 and $N_2{}^+$ is: *(2000)*

a. $N_2 > N^+_2$ b. $N_2 = N^+_2$
c. $N^+_2 > N_2$ d. None

126. Which one is not paramagnetic among the following (Atomic number : Be = 4, Ne = 10, As = 33, Cl = 17) *(1999)*

a. Cl^- b. Be^+
c. Ne^{2+} d. As^+

127. The number of anti-bonding electrons pairs in O_2^{2-} molecular ion on the basis of molecular orbital theory is (atomic no. of O is 8): *(1998)*

a. 3 b. 2
c. 5 d. 4

128. N_2 and O_2 are converted into monocations, N_2^+ and O_2^+ respectively. Which is wrong? *(1997)*

a. In O_2^+ paramagnetism decreases.
b. N_2^+ becomes diamagnetic.
c. In N_2^+, the N–N bond weakens.
d. In O_2^+, the O–O bond order increases.

129. N_2 and O_2 are converted into monoanions, N_2^- and O_2^- respectively, which of the following statements is wrong? [MR*] *(1997)*

a. In O_2^-, bond length increases
b. N_2^- becomes diamagnetic
c. In N_2^-, then N–N bond weakens
d. In O_2^-, the O–O bond order decreases

130. Which of the following species is paramagnetic? *(1995)*

a. CO b. CN^-
c. O_2^{2-} d. NO

131. The ground state electronic configuration of valence shell electrons in nitrogen molecule (N_2) is written as $\sigma 2s^2$, $\sigma^* 2s^2$, $\pi 2p_x^2 = \pi 2p_y^2$ $\sigma 2p_z^2$

Hence the bond order in nitrogen molecule is: *(1995)*

a. 2 b. 3
c. 0 d. 1

132. Which of the following molecules has the highest bond order? *(1994)*

a. O_2^- b. O_2
c. O_2^+ d. O_2^{2-}

Hydrogen Bonding

133. Which one of the following compounds shows the presence of intramolecular hydrogen bond? *(2016 - II)*

a. Cellulose b. Concentrated acetic acid
c. H_2O_2 d. HCN

134. In X – H– – –Y, X and Y both are electronegative elements: *(2001)*

a. Electron density on X will increase and on H will decrease
b. In both electron density will increase
c. In both electron density will decrease
d. On X electron density will decrease and on H increases

135. Strongest hydrogen bond is shown by: *(1992)*

a. Water b. Ammonia
c. Hydrogen fluoride d. Hydrogen sulphide

136. Which one shows maximum hydrogen bonding? [MR*] *(1990)*

a. H_2O b. H_2Se
c. H_2S d. HF

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Answer Key

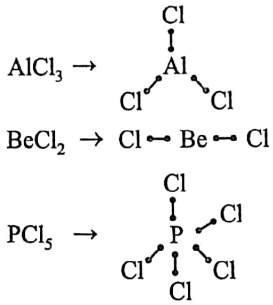
1. (b)	**2.** (d)	**3.** (d)	**4.** (c)	**5.** (d)	**6.** (d)	**7.** (b)	**8.** (c)	**9.** (b)	**10.** (b)
11. (b)	**12.** (d)	**13.** (d)	**14.** (d)	**15.** (b)	**16.** (b)	**17.** (c)	**18.** (d)	**19.** (c)	**20.** (b)
21. (d)	**22.** (b)	**23.** (d)	**24.** (c)	**25.** (c)	**26.** (c)	**27.** (b)	**28.** (c)	**29.** (c)	**30.** (c)
31. (c)	**32.** (b)	**33.** (c)	**34.** (b)	**35.** (b)	**36.** (a)	**37.** (c)	**38.** (b)	**39.** (c)	**40.** (b)
41. (c)	**42.** (a)	**43.** (d)	**44.** (d)	**45.** (d)	**46.** (a)	**47.** (a)	**48.** (a,d)	**49.** (b)	**50.** (a)
51. (c)	**52.** (b)	**53.** (a)	**54.** (b)	**55.** (d)	**56.** (a)	**57.** (d)	**58.** (a)	**59.** (c)	**60.** (b)
61. (a)	**62.** (c)	**63.** (c)	**64.** (d)	**65.** (d)	**66.** (d)	**67.** (c)	**68.** (d)	**69.** (c)	**70.** (b)
71. (a)	**72.** (b)	**73.** (b)	**74.** (b)	**75.** (b)	**76.** (d)	**77.** (c)	**78.** (c)	**79.** (a)	**80.** (a)
81. (c)	**82.** (b)	**83.** (a)	**84.** (b)	**85.** (d)	**86.** (c)	**87.** (c)	**88.** (d)	**89.** (b)	**90.** (b)
91. (b)	**92.** (b)	**93.** (b)	**94.** (d)	**95.** (a)	**96.** (a)	**97.** (a)	**98.** (a)	**99.** (b)	**100.** (a)
101. (b)	**102.** (b)	**103.** (c)	**104.** (a)	**105.** (d)	**106.** (c)	**107.** (b)	**108.** (b)	**109.** (a)	**110.** (c)
111. (b)	**112.** (a)	**113.** (a)	**114.** (b)	**115.** (c)	**116.** (a)	**117.** (b)	**118.** (c)	**119.** (a)	**120.** (a)
121. (a)	**122.** (c)	**123.** (a)	**124.** (c)	**125.** (a)	**126.** (a)	**127.** (d)	**128.** (b)	**129.** (b)	**130.** (d)
131. (b)	**132.** (c)	**133.** (a)	**134.** (a)	**135.** (c)	**136.** (a)				

Explanations

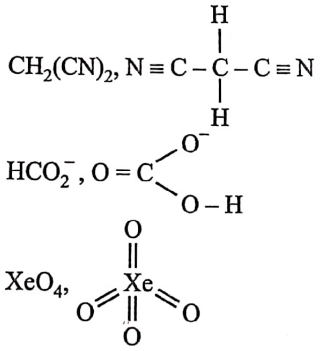
1. (b) $AlCl_3$, $BeCl_2$ and PCl_5 does not obey octet rule.

$AlCl_3$ and $BeCl_2$ both are electron-deficient species having six electrons in valence shell of central atom whereas PCl_5 has ten electrons in valence shell of phosphorous.

The structures are :



2. (d) $(CN)_2$, $N \equiv C - C \equiv N$ $(3\sigma + 4\pi)$

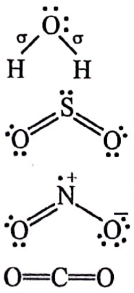


$CH_2(CN)_2$, $N \equiv C - C - C \equiv N$ $(6\sigma + 4\pi)$

HCO_2^-, $O = C$ $(4\sigma + 1\pi)$

XeO_4, $(4\sigma + 4\pi)$

3. (d) The structures of the given species are:



$O=C=O$

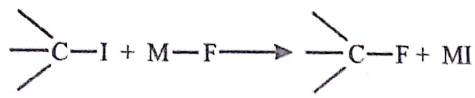
The above structures clearly indicate the presence of pi-bond.

According to the structure of water, it contains only sigma bonds.

4. (c) Electron-deficient species are those which have electrons less than 8 in their valence shell.

Among the 4 options, $(CH_3)_2$, $(SiH_3)_2$ and PH_3 all have complete octets with $8e^-$. But BH_3 has only $6e^-$ and act as a Lewis acid.

5. (d) For the reaction



The reaction will be faster with Rb because lattice energy of RbF is less than LiF, NaF, KF due to large size of Rb^+

6. (d) According to Fajan's Rule, the smaller the cation and the larger the anion, the greater the covalent character of the ionic bond. And, more the covalent character, less will be the melting point.

CaI_2 has the lowest melting point with the most covalent character and lowest lattice energy.

7. (b) Caesium Fluoride (CsF) have largest cation to anion ratio as Cs^+ being the biggest cation and F^- being the smallest anion, among their groups.

8. (c) The alkali metal ion exist as hydrated ion $M^+ (H_2O)_n$ in aqueous solution. With decrease in ionic size, degree of hydration increases hence, Na^+ is mostly hydrated. Since mobility of ion is inversely proportional to size of their hydrated ion, hence increasing order of ionic mobility is: $Cs^+ > Rb^+ > K^+ > Na^+$

9. (b) Smaller the atom, stronger is the bond and greater the bond dissociation energy. Therefore, the bond C–D has the greatest energy and hence has the smallest atoms.

10. (b) Compounds that contain ions of same charge, lattice energy increases as the size of ions decreases. Since anion is same in all, therefore, size of cation will be checked. The correct order for the size of cation is:

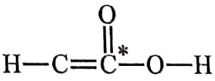
$Cs^+ < Rb^+ < K^+ < Na^+$

Hence, NaF has highest lattice energy.

11. (b) The strength of interaction follows the order:

Van der Waals < hydrogen-bond < dipole-dipole < covalent.

It is so because bond length of H-bond is larger than that of a covalent bond. Also, covalent bond is strongest because, the greater the extent of overlapping, the stronger is the bond formed.

12. (d) 

The asterisk (*) marked carbon has a valency of 5 and hence this formula is not correct because carbon has a maximum valency of 4.

13. (d) Metallic bonds have electrostatic attraction on all sides and hence do not have directional characteristics.

14. (d) HF has the highest dipole moment due to highest electronegativity

$HF > NH_3 > H_2S > \underset{\text{(Non-polar)}}{CH_4}$

15. (b) CO_2 (Bond angle = 180°)

NH_4^+ (Bond angle = 109.5°)

NH_3 (Bond angle = 107°) (N atom has one lone pair)

$H_2O \rightarrow$ (Bond angle = 104.5°)

(oxygen atom has two lone pair

Due to lone pair- lone pair replulsions, the bond angle water decreases more in comparison to NH_3.

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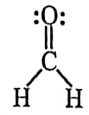
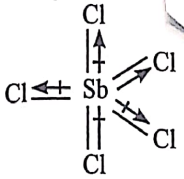
16. (b) Among the given options, only $SbCl_5$ is non-polar in nature, rest other are polar in nature.

CH_2O



Polar molecule

$SbCl_5$



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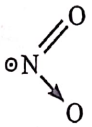
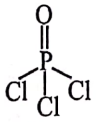
It has zero dipole moment because sum of bond moments is zero, hence non-polar molecule.

NO_2



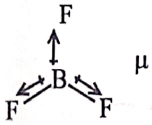
Polar molecule because of presence of one unshared electron.

$POCl_3$

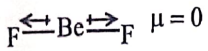


Polar molecule due to uneven distribution of electrons.

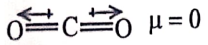
17. (c) The given set of molecules have dipole moment zero because dipoles of the bond cancel each other.



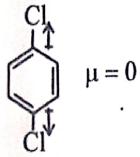
$\mu = 0$



$\mu = 0$



$\mu = 0$



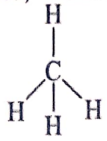
$\mu = 0$

18. (d) $CN^- = 6 + 7 + 1 = 14$

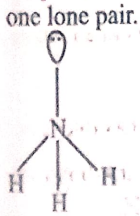
$CO = 6 + 8 = 14$

These two species are isoelectronic and isostructural in nature. Therefore, they both have same bond order.

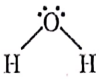
19. (c) CH_4 – sp^3 hybridised, tetrahedral, bond angle 109°29′



NH_3 – sp^3 hybridised, bond angle – 107° due to presence of one lone pair.

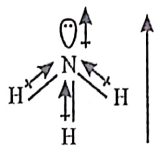


H_2O – sp^3 – bent shaped, bond angle - 104°5′ due to presence of two lone pairs.



So, bond angle of H_2O is less than that of NH_3 & CH_4.

20. (b) Among the given options, dipole moment of NH_3 will be the highest because of same direction of lone pair and resultant dipole moment of the N-H bonds. Its structure is:



Net dipole moment = 1.83 D

21. (d) The lowest energy structure for a compound would be the one that will have the smallest value of formal charges on its central atom.

$$\text{Formal charge of an atom} = V - N - \frac{1}{2} \times B$$

Where, V is the total number of valence electrons, N is the non bonding electrons and B is the bonded electrons.

(i) The formal charge of the sulphur atom, as per the Lewis structure, will be:
$= 6 - 0 - 1/2 \times 8 = +2$

(ii) The formal charge of the sulphur atom will be:
$= 6 - 2 - 1/2 \times 6 = +1$

(iii) The formal charge of sulphur will be:
$= 6 - 0 - 1/2 \times 8 = +2$

(iv) The formal charge of sulphur will be:
$= 6 - 0 - 1/2 \times 12 = 0$

So, we can see that the last option has the lowest value of formal charge, so, it will be more stable than other structures and have the lowest energy.

22. (b) A double bond is always shorter than a single bond. Hence, the increasing order of bond length is:

$C = C < C - C$.

Among the bonds $C - H < C - O < C - C$, the $C - H$ bond is shortest as both hydrogen and carbon atoms are small in size and have small electronegativity differences.

So, the order is: $C - H < C - O$ and $C - H < C - C$

Hence, the correct order of increasing bond length is:

$C - H < C = C < C - O < C - C$

23. (d) In ClO_2^- there are 2 *l.*p of electrons present on the central chlorine atom which repel each other due to which two oxygen atoms come closer leading to decrease in bond angle. Therefore, the bond angle in ClO_2^- is less than 118° which is bond angle in ClO_2 containing less number of electrons on chlorine.

$ClO_2^- < Cl_2O < ClO_2$

$110°\quad 111°\quad 117°$

24. (c) Covalency depends on 2 criteria – first the charge on the ionic species, (Charge is same on all species) Second, the size of anion will determine the covalent character. More the size, more will be the covalent character. The correct order of size of anion is :

$I^- > Br^- > Cl^- > F^-$

Hence, the order becomes:

$MI > MBr > MCl > MF$

25. **(c)** As the no. of l.p of e^-s increases, bond angles decreases. NO_2^+ ion has linear structure with sp hybridisation, hence bond angle is 180°

In NO_2^- N-atom-undergoes sp^2 hybridisation. Due to presence of l.p on N-atom bond angle decreases from 120° to 115°

In NO_2 molecule, N-atom has one unpaired e^- in sp^2 hybrid orbital. The bond angle should be 120° but actually it is 132° due to presence of one unpaired e^- in sp^2 hybrid orbital

$\therefore$ Increasing order of bond angle is:

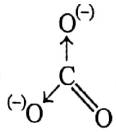
$NO_2^- < NO_2 < NO_2^+$

26. **(c)** More the value of the bond order, the smaller will be the bond length.

$$\text{Bond-order (BO)} = \frac{\text{Total number of bonds associated between two atoms in all structure}}{\text{Total number of canonical forms}}$$

(a) $CO \rightarrow C \equiv O \rightarrow BO = \frac{3}{1} = 3$

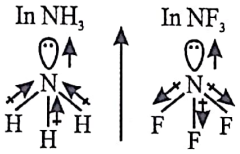
(b) $CO_2 \rightarrow O = C = O \rightarrow BO = \frac{4}{2} = 2$

(c) $CO_3^{2-} \rightarrow$  $\rightarrow BO = \frac{4}{3} = 1.33$

Hence, the order of bond length is:

$CO < CO_2 < CO_3^{2-}$

27. **(b)** Dipole moment of $NH_3 > NF_3$ is because of orientation of dipole moments.



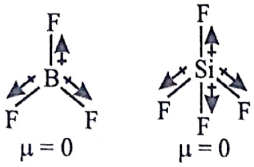
In NH_3, the dipole moments between the lone pair & N-H gets added but in NF_3, there is a net cancellation of dipole moments.

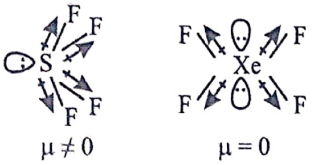
28. **(c)** Covalency depends on 2 factors: Polarisation or polarisability, charge and cation size. More the charge, more the overlapping tendency hence more covalent character, Since Cl^- is common in all, therefore, it will be decided on the basis of size of the cation. The correct order of size of cation is:

$Be^{2+} < Li^+ < Na^+$

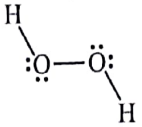
29. **(c)** Molecules having symmetrical shape have zero dipole moment while those which are unsymmetrical (having lone pairs) have permanent dipole moment.

Among the given options, SF_4 contains one lone pair while all others do not contain any lone pairs.

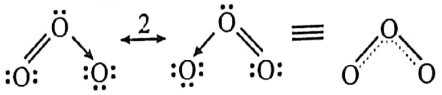




30. **(c)** The structure of hydrogen peroxide is an open boo having bond order =1



Bond order of ozone is 1.5 and its structure is:



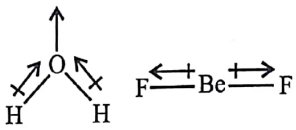
Bond order of O_2 is 2.

Bond order and bond length are inversely related to eac other.

Hence, the O — O bond length increases in the order :

$O_2 < O_3 < H_2O_2$

31. **(c)** In BeF_2, dipole moment is zero because of its linea shape (no lp around central atom), while water has net dipol moment because of its angular shape (because of presence o lone pairs) and hence, is dipolar.

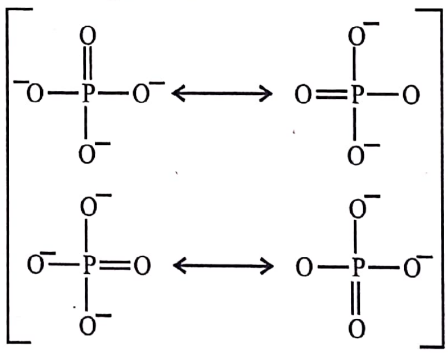


32. **(b)** Sigma bond is formed by head to head overlappin (effective overlapping) while the formation of π bond take place by side to side overlapping. As a result, the strengt of sigma bond is higher than that of π bond. Higher th strength, higher will be the energy.

33. **(c)** Bond order

$$= \frac{\text{no. of bond in all possible direction}}{\text{Total no. of resonating structure}} = \frac{5}{4} = 1.25$$

Resonating structure are:

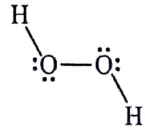


Total charge on PO_4^{3-} ion is –3.

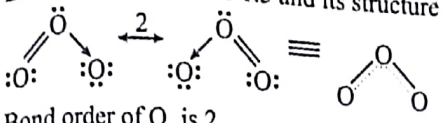
So, the average formal charge on each 'O' atom is $= -\frac{3}{4} = -0.7$

34. **(b)** The C–C bond length = 1.54 Å C=C bond length = 1.34 and C ≡ C bond length = 1.20 Å Since propyne has a trip bond, therefore it has minimum bond length.

35. **(b)** The structure of hydrogen peroxide is an open boo having bond order =1



Bond order of ozone is 1.5 and its structure is:



Bond order of O_2 is 2.

Bond order and bond length are inversely related to each other. Hence, the O—O bond length increases in the order :
$O_2 < O_3 < H_2O_2$

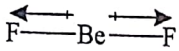
36. **(a)** The structure of CS_2 is linear which is symmetrical and therefore, it does not have permanent dipole moment. It is represented as S = C = S.

37. **(c)** There is a triple bond in ethyne molecule (H—C≡C—H) and due to this triple bond, carbon-carbon bond distance is shortest in ethyne.

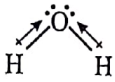
38. **(b)** The structure of CCl_4 is tetrahedral in which each Cl atom is present at the corners. For tetrahedral, bond angle is equal to 109° 28'.

39. **(c)** Along the period, electronegativity (*EN*) increases and hence as we move from Li → Be → B → C, the electronegativity increases and hence the *EN* difference between the element and Cl decreases and accordingly the covalent character increases. Hence, $LiCl < BeCl_2 < BCl_3 < CCl_4$ is the correct order.

40. **(b)** Dipole moment depends on the symmetry of the molecule. If the molecule is symmetrical with regular geometry then, it has zero dipole moment otherwise non zero. Since, BeF_2 is linear, it has zero dipole moment.



H_2O is a bent molecule and hence, it has a non-zero dipole moment.



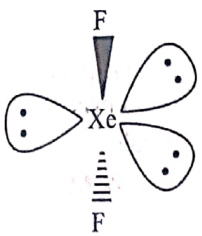
41. **(c)**

Molecules		Shape
NH_3	–	Trigonal pyramidal
ClF_3	–	T-Shape
PCl_5	–	Trigonal bipyramidal
BrF_5	–	Square pyramidal

42. **(a)** The hybridization of XeF_2 is:

$$XeF_2 = \frac{1}{2}(8+2) = 5$$

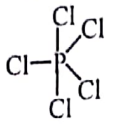
Its hybridization is sp^3d^2 and its structure is:



Linear

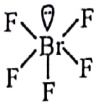
XeF_2 has maximum 3 lone-pair – lone-pair repulsions. In ClF_3 two lone pairs, in IF_5 & SF_4, only one lone pair is present. Whereas, in XeF_2, three lone pairs are present.

43. **(d)** Geometry of PCl_5 – Trigonal bipyramidal (sp^3d)



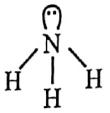
Geometry of SF_6 – Octahedral (sp^3d^2)

Geometry of BrF_5 – Square pyramidal (sp^3d^2)

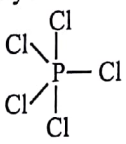


Geometry of BF_3 – Trigonal Planar (sp^2)

44. **(d)** The shape of NH_3 is pyramidal due to presence of one lone pair having sp^3 hybridization.



The structure of PCl_5 is trigonal bipyramidal having sp^3d hybridization.

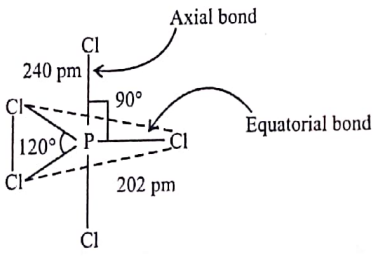


The structure of SF_6 is octahedral having sp^3d^2 hybridization.

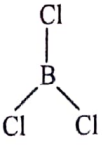
The structure of $BeCl_2$ is linear having sp hybridization.

Cl—Be— Cl

45. **(d)** PCl_5 contains two types of bonds- axial and equatorial. Axial bonds are slightly longer due to the repulsion caused by the equatorial bonds, thus making them weaker, as a result, PCl_5 is a reactive molecule.



46. **(a)** The structure of BCl_3 is trigonal planar having bond angle 120° according to VSEPR theory.



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47. (a) ScF_3 and CH_4 do not have same shape. ScF_3 is AB_3L type molecule with 4 bond pair and 1 lone pair with shape see–saw. CH_4 is AB_4 type molecule with no lone pair and tetrahedral shape.

I_3^+ have 2 lone pairs with bent/angular shape. $BiCl_5$ does not exists because of inert pair effect. SO_2 type molecule have both $p\pi - p\pi$ & $d\pi - p\pi$ bonds.

48. (a,d)

The shape of CO_3^{2-} is trigonal planar having sp^2 hybridization. Number of electrons:

6(from C) + 3 × 8(from O) + 2(charge) = 32

The shape of NO_3^- is trigonal planar having sp^2 hybridization. Number of electrons:

7(from N) + 1(charge) + 3 × 8(from O) = 32

The shape of ClO_3^- is pyramidal having sp^3 hybridization. Number of electrons:

17(from Cl) + 1(charge) + 3 × 8(from O) = 42

The shape of SO_3^{2-} is pyramidal having sp^3 hybridization. Number of electrons:

16(from S) + 2(charge) + 3 × 8(from O) = 42

a → CO_3^{-2} → sp^2 → trigonal planar; 32e⊖

a → NO_3^- → sp^2 → trigonal planar; 32e⊖

d → ClO_3^-, SO_3^{2-} → 42 e⁻ → iso structural; sp^3 → trigonal pyramidal

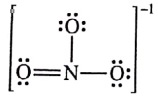
49. (b) Order of repulsing force according to VSEPR theory is lone pair – lone pair > lone pair – bond pair > bond pair – bond pair.

50. (a) The structure of NO_2^+ is:

$O{=}\overset{+}{N}{=}O$

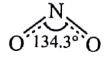
Its shape is linear having bond angle 180°.

The structure of NO_3^- is:



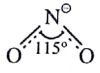
Its structure is planar having bond angle 120°.

The structure of NO_2 is:



It contains odd number of electrons having bond angle of 134°.

The structure of NO_2^- is:

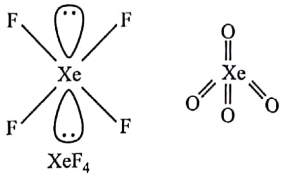


It contains one lone pair due to which bond angle decreases to 115°.

51. (c) In diamond and silicon carbide, central atom is hybridised and hence, both are isostructural.

NH_3 and PH_3 both are pyramidal and central atom in b cases is sp^3 hybridised. $SiCl_4$ and PCl_4^+, both are tetrahed and central atom in both cases is sp^3 hybridised.

In XeF_4, Xe is sp^3d^2 hybridised and structure is squ planar while in XeO_4, Xe is sp^3 hybridised and structure tetrahedral.



52. (b) The shape of ClO_3^- is pyramidal having sp^3 hybridizati Number of electrons:

17(from Cl) + 1(charge) + 3 × 8(from O) = 42

The shape of SO_3^{2-} is pyramidal having sp^3 hybridizati Number of electrons:

16(from S) +2 (charge) + 3×8(from O) = 42

53. (a) Species which do not contain lone pairs have symmetri shape and those contain lone pairs have distorted shape.

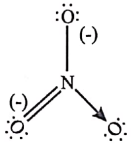
Hybridisation of-

N_3^- - sp (Linear)

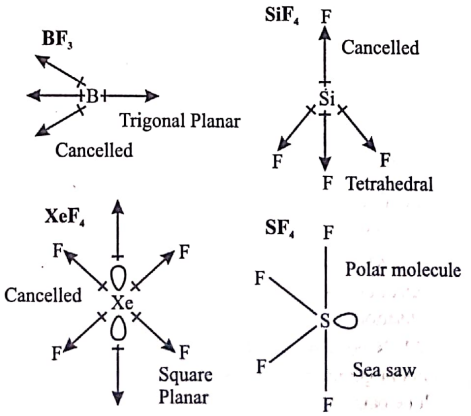
NO_3^- - sp^2 (Trigonal Planar)

NO_2^- - sp^2 (Trigonal Planar → Shape, bent → geometry

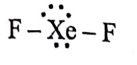
CO_2 - sp (Linear)

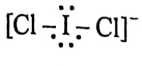


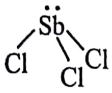
54. (b) Species having symmetrical shape are non-polar in nat and those which have unsymmetrical shape (due to prese of lone pairs) are polar in nature.

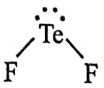


55. (d) Isostructural species are those which have same shape.

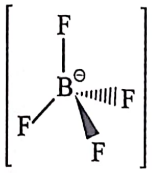
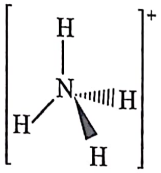

sp^3d, Linear


sp^3d, Linear


sp^3, Pyramidal


sp^3, Pyramidal

56. (a) Both BF_4^- & NH_4^+ have sp^3 hybridised around central atom and exhibit tetrahedral geometry.

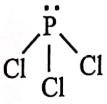



57. (d) The structures of the species are given below as:

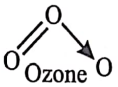
2 bond pairs, 2 lone pairs

3 bond pairs, 0 lone pair

2 bond pairs, 2 lone pairs


3 bond pairs, 1 lone pair

58. (a) Angular shape of an ozone molecule consists of 1 pi bond and 2 sigma bonds. Its structure is:

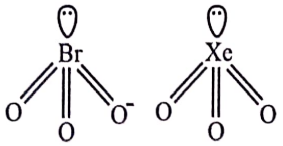


59. (c) Hybridisation of Br in BrO_3^-.

$\frac{1}{2}(7+0-0+1) \Rightarrow sp^3$

Hybridisation of XeO_3

$\frac{1}{2}(8+0-0) = 4 \Rightarrow sp^3$

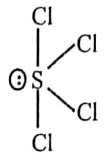


Structure is trigonal pyramidal in both molecules, hence they are isostructural.

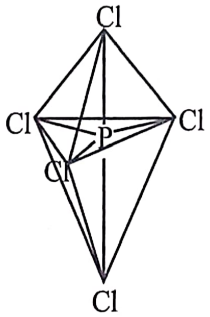
60. (b) In ClF_3 all bonds are not equal due to TBP geometry of ClF_3 molecule.

BF_3 and AlF_3 show trigonal symmetric structure due to sp^3 hybridisation. NF_3 show 5 pyramidal structure due to sp^3 hybridisation.

61. (a) SCl_4 is not isostructural with $SiCl_4$. They have trigonal pyramidal geometry and sea-saw shaped due to presence of one lone pair.



62. (c) It's not necessary that every AB_5 type compound have square pyramidal structure, it can have trigonal pyramidal geometry. For example PCl_5. The structure can vary according to the number of lone pairs present on the central atom.



63. (c) NO_2^+ has linear structure with sp hybridisation.

$O{-}N \equiv O^+$

64. (d) Hybridisation of B in BF_3 is:

$\frac{1}{2}(3+3) = 3$

Hence, BF_3 has sp^3 hybridisation with trigonal planar geometry.

65. (d) Hybridisation state $= \frac{1}{2}$ (V.E + MA − C + A)

For SiF_4:

Hybridisation state $= \frac{1}{2}(4+4) = 4$

Hence, it has a tetrahedral shape.

For SF_4:

Hybridisation state $= \frac{1}{2}(6+4) = 5$

Hence, it has trigonal bipyramidal geometry.

Since sulphur has formed only four bonds with the fluorine atoms, it must have one lone pair. Due to the presence of lone pairs, its shape will become see-saw.

Thus, these two are not isostructural as they have different shapes.

66. (d) In octahedral molecule, six hybrid orbital are directed towards the corners of a regular octahedron with a bond angle of 90°.

Here, X — M — X bonds at 180° must be three.

67. (c) BrF_3 has sp^3d hybridisation because there are three bonding Br — F pairs and two lone pairs on Br, and it adopts trigonal bipyramidal geometry. In this geometry, lone pairs are always kept at equatorial positions because of minimum repulsion. Having both the lone pair at the axial positions will create 6 lone pair-bond pair repulsions. Having one of the lone pairs at the axial position will create one lone pair-lone pair repulsion and three lone pair-bond pair repulsions. But the lone pair at the equatorial position will have only four lone pair-bond pair repulsions and hence minimizes both types of repulsion, i.e. lp — lp repulsion and bp — lp repulsion.

68. (d) The structure of NO_3^- is:
In NO_3^- ion, nitrogen has 4 bond pair of electrons and no lone pair of electrons.

69. (c) In CO, the number of electrons = 6 + 8 = 14
CN^- have also got 6 + 7 + 1 = 14 electron.

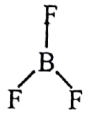
70. (b) Bond angle is maximum in NH_4^+, tetrahedral molecule with bond angle 109°.

71. (a) Compound having same shape with same hybridisation are known as iso-structural. XeF_2, IF_2^- → both are sp^3d hybridised and have linear structure.

72. (b) There is no lone pair on boron in BCl_3 hence, no repulsion takes place. There is a lone pair on nitrogen in NCl_3 hence, repulsion takes place. Therefore, BCl_3 is a planar molecule but NCl_3 is a pyramidal molecule.

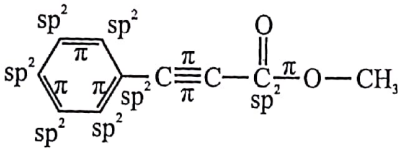
73. (b) CO_2 molecule is sp-hybridised and thus it is linear, while CO_3^{2-} is planar (sp^2-hybridised), SO_2 is an angular molecule with sp^2 hybridisation, SO_4^{2-} is tetrahedral (sp^3-hybridised).

74. (b) Geometry of BF_3 molecule is Trigonal Planar.
Hybridization of B is sp^2.



The number of valence electrons around the central atom that is Boron in BF_3 molecule is 6.

75. (b) sp^2 hybridized carbon involves the mixing of one 's' and two 'p' orbitals of equal energy. (i) Number of sp^2 hybridised carbon atoms is 7.
(ii) Number of pi bonds is 6.



76. (d) Potential energy of two H atoms at infinite distance = a
Potential energy of two H atoms at distance equal to bond length = b
So, the bond energy of H_2 = (b – a)

77. (c) Hybridisation state = Number of σ bond + number of lone pair or

Hybridisation state → from steric number rule

$$\text{Hybridisation state} = \frac{1}{2}(\text{V.E} + \text{MA} - \text{C} + \text{a})$$

$$\text{For, } NO_2^+ = \frac{1}{2}(5+0-1)$$
$$= 2 \rightarrow sp$$

$$NO_3^- = \frac{1}{2}[5+0+1]$$
$$= 3 \rightarrow sp^2$$

$$NH_4^+ = \frac{1}{2}[5+4-1]$$
$$= 4 \rightarrow sp^3$$

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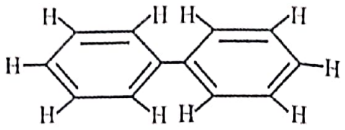
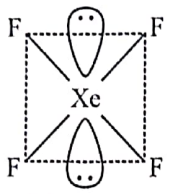
78. (c)



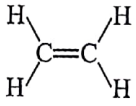
Coplanar are in a plane or where all C atoms are sp^2 hybridised. In the above structure, all atoms are coplanar.

79. (a) According to VSEPR theory, the structure of XeF_4 is square planar having two lone pairs. Its hybridization is sp^3d^2.

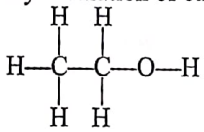


sp^3d^2 hybridisation (octahedral geometry, square planar shape)

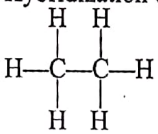
80. (a) Hybridisation of CO_2 is sp. Its structure is: O = C = O
and of ethyne C_2H_2 is sp. Its structure is: H – C ≡ C – H
Hybridization of ethene is sp^2. Its structure is:



Hybridization of ethanol is sp^3. Its structure is:



Hybridization of ethane is sp^3. Its structure is:



81. (c) $CH_3 - C \equiv C - CH_3$ has carbon in sp hybridisation and therefore, has linear geometry.

82. (b) Among all the species, NO_2^- and NO_3^- have sp hybridisation with planar geometry showing resonance.

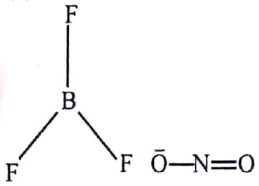
83. (a) Hybridisation of NO_3^- is sp^2. It has a planar structure exhibiting resonance.
H_3O^+ - sp^3 hybridisation with tetrahedral geometry.

84. (b) In SF_4, hybridisation is sp^3d.
Hybridisation = 1/2 (No. of σ bond + no. of atoms attached ± charge

$$\frac{6+4}{2} = \frac{10}{5} = 5$$

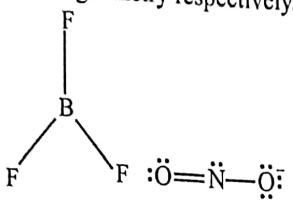
85. (d) sp^3d hybridisation is present in PCl_5, SF_4, I_3^-
But sp^3d^2 hybridisation is present in $SbCl_5^{2-}$.

86. (c)

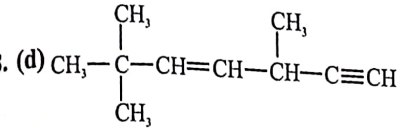


Both showing planar geometry with sp^2 hybridisation. Rest all NH_2^-, NH_3, H_2O are sp^3 hybridised.

87. **(c)** BF_3 and NO_2^- have sp^2 hybridisation having planar geometry and linear geometry respectively.



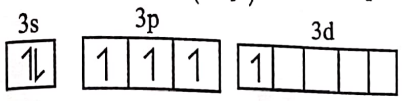
88. **(d)**



Hybridisation of C_2, C_3, C_5, and C_6 are as follows:
sp, sp^3, sp^2, sp^3.

89. **(b)** More the '*s*' character, more will be the electronegativity
The correct of s-character is:
$sp > sp^2 > sp^3$
50% 33.3% 25%
Therefore, the correct order regarding the electronegativity of hybrid orbitals of carbon is also the same.

90. **(b)** In sulphite ion $(SO_3^{-2}) \rightarrow$ 'S' is sp^3 hybridised

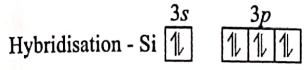


Excited state of 'S' atom
3p - e^- form σ bond with three 'O' - atom,
d - electron form π bond with one oxygen atom
Therefore, it has pπ = dπ - bonding.

91. **(b)** For strong π-bonding, pπ – pπ bonding should be strong. Due to larger size of P, pπ – pπ bonding is weak as compared to N-atom.

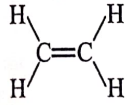
92. **(b)** In PO_4^{3-}, P atom has vacant d-orbitals, thus it can form pπ – dπ bond. 'N' and 'C' have no vacant 'd' orbital in their valence shell so, they cannot form such bond.

93. **(b)** $Si(CH_3)_4$ = tetramethyl silane



Therefore, there is sp^3 hybridisation. Structure is tetrahedral.

94. **(d)** $BeCl_2$ and C_2H_2 have sp-hybridisation and C_2H_6 has sp^3-hybridisation. C_2H_4 has sp^2 hybridization. Its structure is:



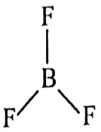
95. **(a)** According to VSEPR theory, a molecule with sp^3d^2 hybridisation must be octahedral.

96. **(a)** A σ-bond is stronger than a π-bond. In sigma bond, head to head overlapping takes place while in π bond, side wise overlapping takes place.

97. **(a)** When two hybridised orbitals belonging to two atoms undergoes linear combination, they form sigma bond.

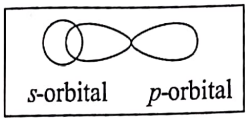
98. **(a)** For linear arrangement of atoms, the hybridisation is sp. (bond angle = 180°).
Only H_2S has sp^3-hybridisation and hence, it has angular shape while C_2H_2, BeH_2 and CO_2 all involve sp-hybridisation and hence has linear arrangement of atoms.

99. **(b)** Hybridisation state = Number of σ bond + number of lone pair



From the structure, we can see that
Number of σ bond = 3
Number of lone pair = 0
Hence, Hybridisation state = 3 which corresponds to sp^2 hybridisation.

100. **(a)** The type of overlap between *s*- and *p*-orbitals occurs along internuclear axis and hence, the angle is 180°.



s-p overlapping

101. **(b)** Equilateral or triangular planar shape involves sp^2 hybridisation. *e.g.*, BCl_3.

102. **(b)** $\sigma 1s < \sigma^* 1s < \sigma 2s < \sigma^* 2s < (\pi 2p_x = \pi 2p_y) <$

$\sigma 2p_z < (\pi^* 2p_x = \pi^* 2p_y) < \sigma^* 2p_z$

is the correct order of energy of MO for homo nuclear diatomic species N_2.

103. **(c)** During the formation of BMO, the two electron waves of the bonding atoms reinforce each other because of constructive interference.

Molecular orbitals that are obtained from $2P_x$ and $2P_y$ orbitals are 'unsymmetrical' in nature around bond axis.

104. **(a)** Electronic configuration of oxygen molecule is:
$(O_2) = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2, \pi 2p_x^2 = \pi 2p_y^2,$
$\pi^* 2p_x^1 = \pi^* 2p_y^1$

Bond order for $O_2 = \frac{10-6}{2} = \frac{4}{2} = 2$

Bond order for $O_2^+ = \frac{10-5}{2} = \frac{5}{2} = 2.5$

Bond order for $O_2^- = \frac{10-7}{2} = \frac{3}{2} = 1.5$

Bond order for $O_2^{2-} = \frac{10-8}{2} = \frac{2}{2} = 1$

O_2^+ contains unpaired $e^-_s \Rightarrow$ paramagnetic
$\Rightarrow$ Electronic configuration of C_2 molecule is:
$C_2\ (14e^-) = \sigma 1s^2\ \sigma^* 1s^2\ \sigma 2s^2\ \sigma^* 2s^2 (\pi 2p_x^2 = \pi 2p_y^2)\ \sigma\ 2p_z^2$
Therefore, it is clear that C_2 molecule has four electrons in its two degenerate π molecular orbitals.

No. of electrons in H_2^+ ion is = 2 – 1 = 1

105. **(d)** For He_2 molecule:
Electronic configuration is $\sigma 1s^2, \sigma^* 1s^2$.

$$B.O = \frac{1}{2}(N_b - N_a) \qquad = \frac{1}{2}(2-2) = 0$$

The bond order comes out to be zero. This indicates that there is no bond formation between 2 He atoms and hence, He_2 molecule does not exist.

106. **(c)** MO configuration of C_2 is:

$\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \pi 2p_x^2 = \pi 2p_y^2$

Double bond in C_2 consists of both π bonds because of the presence of four electrons in two π molecular orbitals.

107. **(b)** NO : $(\sigma 1s)^2, (\sigma^* 1s)^2, (\sigma 2s)^2, (\sigma^* 2s)^2, (\sigma 2p_z)^2, (\pi 2p_x)^2 = (\pi 2p_y)^2, (\pi^* 2p_x)^1 = (\pi^* 2p_y)^0$

$$BO = \frac{10-5}{2} = 2.5$$

CN^- : $(\sigma 1s)^2, (\sigma^* 1s)^2, (\sigma 2s)^2, (\sigma^* 2s)^2, (\pi 2p_x)^2 = (\pi 2p_y)^2, (\sigma 2p_z)^2$

$$BO = \frac{10-4}{2} = 3$$

CN : $(\sigma 1s)^2, (\sigma^* 1s)^2, (\sigma 2s)^2, (\sigma^* 2s)^2, (\pi 2p_x)^2 = (\pi 2p_y)^2, (\sigma 2p_z)^1$

$$BO = \frac{9-4}{2} = 2.5$$

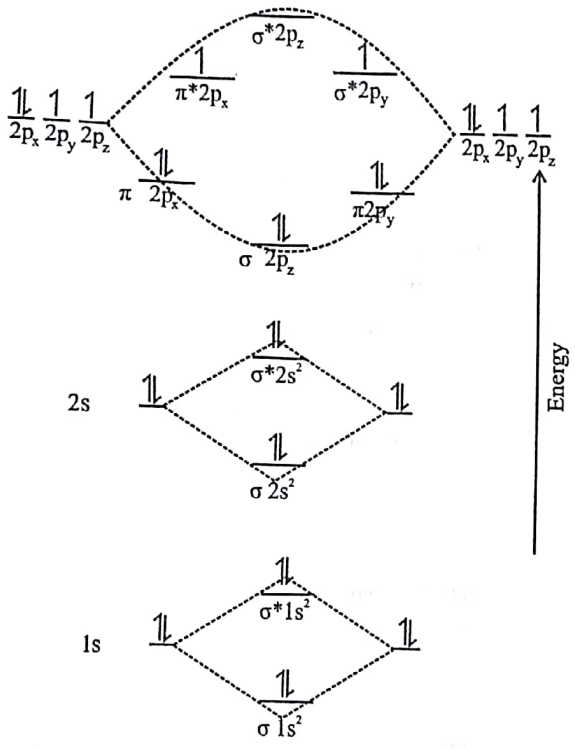
CN^+ : $(\sigma 1s)^2, (\sigma^* 1s)^2, (\sigma 2s)^2, (\sigma^* 2s)^2, (\pi 2p_x)^2 = (\pi 2p_y)^2$

$$BO = \frac{8-4}{2} = 2$$

Hence, option (b) should be the right answer.

108. **(b)** O_2 (atomic number) = 16

Molecular orbital Diagram:



Bond order = $\frac{1}{2}$ (No. of bonding electrons – no. of anti-bonding electrons)

$= 1/2\ (10 - 6) = 2$

Similarly, For $O_2^- = 1.5$

$O_2^{2-} = 1$

and Bond order $\propto \frac{1}{\text{Bond length}} \propto$ stability

$\therefore$ Order of Bond length = $O_2^{2-} > O_2^- > O_2 > O_2^+$

Thus, order of stability will be reverse of it.

109. **(a)** Bond order: $O_2^- = 1.5 \quad O_2 = 2 \quad O_2^+ = 2.5$

$O_2^+ > O_2 > O_2^-$

110. **(c)** Indentation Bond order: $O_2^{2+} = 3, O_2^- = 1.5, O_2^+ = 2.5$

$\rightarrow O_2^{2+} > O_2^+ > O_2^-$

111. **(b)** In paramagnetic species, there is a presence of unpair electrons.

The electronic configuration of O_2^- is:

$O_2^- = 8 + 8 + 1 = 17$

$= \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2, \pi 2p_x^2, \pi 2p_y^2, \pi^* 2p_x^2, \pi^* 2p_y^1$

Since, O_2^- contains one unpaired electron, it is paramagnetic.

112. **(a)** Bond order of $He_2^+ = 0.5$, NO = 2.5, $O_2^- = 1.5$ $C_2^{2-} = 3$ (by using MO

So, $C_2^{2-} > NO > O_2^- > He_2^+$

113. **(a)** Electronic configuration of O_2 is:

$\sigma\ (1s)^2, \sigma^*\ (1s)^2, \sigma\ (2s)^2, \sigma^*\ (2s)^2, \sigma\ (2p_z)^2, \pi\ (2p_x)^2, \pi\ (2p_y$

$\pi^*\ (2p_x)^1 = \pi^*(2p_y)^1$

So, incoming e^- will enter in $\pi^*\ 2p_x$ / $\pi^* 2p_y^1$

114. **(b)** Bond order of O_2^{2-} can be calculated as follows:

$= \sigma 1s^2, \sigma^* 1s^2\ \sigma 2s^2\ \sigma^* 2s^2\ \sigma 2p_z^2\ \pi 2p_x^2\ \pi 2p_y^2\ \pi^* 2p_x^2 \pi^* 2p_y^2$

Bond order = $\frac{N_b - N_a}{2}$ $\quad N_b \rightarrow$ no. of bonding e^-

$= \frac{10-8}{2}$ $\quad N_a \rightarrow$ no. of antibonding $e^- = 1$

= Bond order = 1

The bond order of B_2 can be calculated as follows:

$B_2 = 10e^-$

$\sigma 1s^2\, \sigma^* 1s^2\ \sigma 2s^2 \sigma^* 2s^2\ \sigma 2p_z^2$

$$B.O. = \frac{7-5}{2} = 1$$

Hence, these two have the same bond order.

115. **(c)** $O_2 \Rightarrow \sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \sigma 2p_z^2 (\pi 2p_x^2 = \pi 2p_y^2)(\pi^* 2p_x^1 = \pi^* 2p_y^1)$

O_2 :Bond order $= \frac{1}{2}(8-4) = 2$

O_2^+ :Bond order $= \frac{1}{2}(8-3) = 2\frac{1}{2}$

O_2^- :Bond order $= \frac{1}{2}(8-5) = 1\frac{1}{2}$

O_2^{2-} :Bond order $= \frac{1}{2}(8-6) = 1$

116. **(a)** The electronic configuration of O_2 is:

$O_2 \Rightarrow \sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \sigma 2p_z^2 (\pi 2p_x^2 = \pi 2p_y^2)(\pi^* 2p_x^1 = \pi^* 2p_y^1)$

The electronic configuration of O_2^+ is:

$O_2^+ \Rightarrow \sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \sigma 2p_z^2 (\pi 2p_x^2 = \pi 2p_y^2)(\pi^* 2p_x^1)$

Both O_2^+ and O_2 are paramagnetic in nature since, they conta 1 and 2 unpaired electrons respectively.

117. (b) The electronic configuration of O_2^{2+}

$\sigma ls^2 \sigma 1^* s^2 \sigma 2s^2 \sigma 2^* s^2 \sigma 2p_z^2 (\pi 2p_x^2 = \pi 2p_y^2)(\pi^* 2p_x^1 = \pi^* 2p_y^0)$

$$\text{Bond order} = \frac{N_b - N_a}{2}$$

$$= \frac{10-5}{2} = 2.5$$

$$\text{As, Bond order} \propto \frac{1}{\text{B.L.}}$$

So, O_2^+ exhibits maximum bond order but minimum bond length.

118. (c) The electronic configuration of Be_2 is $\sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2$.

Since $N_b = N_a$ hence, bond order = 0

Species with bond order zero, does not exist under normal condition.

119. (a) Electronic configuration:

$N_2 = \sigma 1s^2 \sigma^* s^2 \sigma 2s^2 \sigma^* 2s^2 (\pi 2p_x^2 = \pi 2p_y^2) \sigma 2p_z^2$

$N_2^- = \sigma ls^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 (\pi 2p_x^2 = \pi 2p_y^2) \sigma 2p_z^2 (\pi^* 2p_x^1 = \pi^* 2p_y^0)$

$N_2^{2-} = \sigma ls^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 (\pi 2p_x^2 = \pi 2p_y^2) \sigma 2p_z^2 (\pi^* 2p_x^1 = \pi^* 2p_y^1)$

Bond order = $N_2^{2-} < N_2^- < N_2$

2 2.5 3

120. (a) $C_2^{2-} \Rightarrow$ Total number of electrons = 14

$\sigma(1s)^2 \sigma^*(1s)^2 \sigma(2s)^2 \sigma^*(2s)^2 \pi(2p_x)^2 \pi(2p_y)^2 \sigma(2p_z)^2$

$$\text{Bond order} = \frac{N_b - N_a}{2} = \frac{10-4}{2} = 3$$

NO $\rightarrow$ Total number of electrons = 7 + 8 = 15

$\sigma(1s)^2 \sigma^*(1s)^2 \sigma(2s)^2 \sigma^*(2s)^2 \sigma(2p_z)^2 \pi(2p_x)^2 \pi(2p_y)^2 \pi^*(2p_x)^1$

$$\text{Bond order} = \frac{10-5}{2} = 2.5$$

$O_2^- \rightarrow$ Total number of electrons = 8 + 9 = 17

$\sigma(1s)^2\ \sigma^*(1s)^2\ \sigma(2s)^2\ \sigma^*(2s)^2\ \sigma(2p_z)^2\ \pi(2p_x)^2\ \pi(2p_y)^2\ \pi^*(2p_x)^2\ \pi^*(2p_y)^1$

$$\text{Bond order} = \frac{10-7}{2} = 1.5$$

$He_2^+ \rightarrow$ Total number of electrons = 1 + 1 = 2

$He_2^+ \Rightarrow \sigma(1s)^2$

$$\text{Bond order} = \frac{2-0}{2} = 1$$

121. (a) Paramagnetic diatomic molecule with atomic number $16 = O_2$.

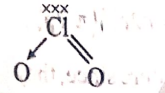
Electronic configuration:

$\sigma 1s^2\ \sigma^*\ ls^2\ \sigma 2s^2\ \sigma^* 2s^2\ \sigma 2p_z^2\ (\pi 2p^2{}_x = \pi 2p_y^2)\ (\pi^* 2p_x{}^1 = \pi^* 2p_y{}^1)$

There are 2 unpaired e^- in orbital $\pi^* 2p_x{}^1$ and $\pi^*\ 2p_y{}^1$.

122. (c) ClO_2 has 1 unpaired e^- in molecular hybridised orbital exhibiting paramagnetic behaviour.

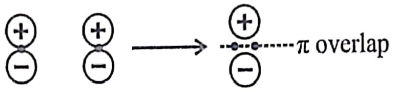
Its structure is:



Paramagnetic

Team Kohinoor
TgI'd - @kohinooraofficial1

123. (a) For π overlap, the lobes of the atomic orbitals are perpendicular to the line joining the nuclei.



P_x P_y

Hence, only side wise overlap takes place.

124. (c) Electronic configuration of CO molecule is:

$\sigma 1s^2\ \sigma^* 1s^2\ \sigma 2s^2\ \sigma^* 2s^2\ \pi^2 2p_y\ \pi^2 2p_x\ \sigma^2 2p_z$

Since, all electrons are paired, therefore it is not paramagnetic.

125. (a) $N_2(14) \rightarrow (\sigma 1s)^2, (\sigma^* 1s)^2, (\sigma 2s)^2,$

$(\sigma^* 2s)^2, (\pi 2p_x)^2, (\pi 2p_y)^2, (\sigma 2p_z)^2$

In N_2, bond order $= \frac{N_b - N_a}{2} = \frac{10-4}{2} = 3$

The electronic configuration of N_2^+ is:

$(\sigma 1s)^2, (\sigma^* 1s)^2, (\sigma 2s)^2, (\sigma^* 2s)^2, (\pi 2p_x)^2, (\pi 2p_y)^2, (\pi 2p_z)^1$

In N_2^+, bond order $= \frac{9-4}{2} = 2.5$

As the bond order in N_2 is more than N_2^+, so, the dissociation energy of N_2 is higher than N_2^+.

126. (a) Paramagnetic character is based upon presence of unpaired electrons.

$_{17}Cl^- = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p_x^2\ 3p_y^2\ 3p_z^2$

$_4Be^+ = 1s^2\ 2s^1$

$_{10}Ne^{2+} = 1s^2, 2s^2 2p_x^2 2p_y^1 2p_z^1$

$_{33}As^+ = 1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}, 4s^2 4p_x^1 4p_y^1 4p_z^0$

Except Cl^- all have unpaired electrons, so, these are paramagnetic in nature.

127. (d) O_2^{2-} (18) $\rightarrow (\sigma 1s)^2, (\sigma^* 1s)^2 (\sigma 2s)^2, (\sigma^* 2s)^2 (\sigma 2p_z)^2, (\pi 2p_x)^2,$

$(\pi 2p_y)^2, (\pi^* 2p_y)^2, (\pi^* 2p_z)^2$

* represents antibonding molecular orbitals.

Thus, the no. of antibonding electrons in O_2^{2-} ion is = 8 (4 pairs)

128. (b) The electron configuration of N_2 is:

$\sigma 1s^2\ \sigma^* 1s^2\ \sigma 2s^2\ \sigma^* 2s^2\ \pi 2p_x^2\ \pi 2p_y^2\ \sigma 2p_z^2$

Since N_2 has no unpaired electron, therefore, it is diamagnetic.

The electronic configuration of N_2^+ is:

$\sigma 1s^2\ \sigma^* 1s^2\ \sigma 2s^2\ \sigma^* 2s^2\ \pi 2p_x^2\ \pi 2p_y^2\ \sigma 2p_z^1$

Since N_2^+ has an unpaired electron, it is paramagnetic.

129. (b) The electronic configuration of O_2 is

$O_2 \Rightarrow \sigma ls^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \sigma 2p_z^2 (\pi 2p_x^2 = \pi 2p_y^2)(\pi^* 2p_x^1 = \pi^* 2p_y^1)$

O_2 has two unpaired electrons in its π orbitals, one electron goes to π^*orbital to form O_2^-.

B.O. of O_2 is = 0.5 [(Number of bonding electrons) – (number of anti-bonding electrons)]

$= 0.5\ [10 - 6] = 2$

Bond order of $O_2^- = 0.5\ [10 - 7] = 1.5$

Therefore, the bond order from O_2 to O_2^- decreases and bond length increases.

14. When 1 mol gas is heated at constant volume, temperature is raised from 298 to 308 K. Heat supplied to the gas is 500 J. Then which statement is correct? [MR*] *(2001)*

a. $q = w = -500$ J, $\Delta U = 0$
b. $q = \Delta U = 500$J, $w = 0$
c. $q = w = 500$ J, $\Delta U = 0$
d. $\Delta U = 0$, $q = w = -500$ J

15. One mole of an ideal gas at 300 K is expanded isothermally from an initial volume of 1 L to 10 L. The ΔE for this process is ($R = 2$ cal mol^{-1} K^{-1}): *(1998)*

a. 163.7 cal
b. Zero
c. 1381.1 cal
d. 9 L atm

16. Which of the following is the correct equation? *(1996)*

a. $\Delta U = \Delta w + \Delta q$
b. $\Delta U = \Delta q - w$
c. $\Delta w = \Delta U + \Delta q$
d. None of these

17. During isothermal expansion of an ideal gas, its: *(1994, 91)*

a. Internal energy increases
b. Enthalpy decreases
c. Enthalpy remains unaffected
d. Enthalpy reduces to zero

Enthalpy Change, ΔH of Reaction

18. Which amongst the following options is the correct relation between change in enthalpy and change in internal Energy? [MR*] *(2023)*

a. $\Delta H + \Delta U = \Delta nR$
b. $\Delta H = \Delta U - \Delta n_g RT$
c. $\Delta H = \Delta U + \Delta n_g RT$
d. $\Delta H - \Delta U = -\Delta nRT$

19. Consider the following process

$\frac{1}{2}A \rightarrow B$ ΔH(kJ/mol) = + 150

$3B \rightarrow 2C + D$ ΔH(kJ/mol) = – 125

$E + A \rightarrow 2D$ ΔH(kJ/mol) = + 350

For $B + D \rightarrow E + 2C$, ΔH will be: *(2011 Mains)*

a. –325 kJ/mol
b. 325 kJ/mol
c. 525 kJ/mol
d. –175 kJ/mol

20. The following two reactions are known:

$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$; $\Delta H = -26.8$ kJ
$FeO(s) + CO(g) \rightarrow Fe(s) + CO_2(g)$; $\Delta H = -16.5$ kJ. The value of ΔH for the following reaction $Fe_2O_3(s) + CO(g) \rightarrow 2FeO(s) + CO_2(g)$ is: [MR*] *(2010 Mains)*

a. +10.3 kJ
b. – 43.3 kJ
c. –10.3 kJ
d. +6.2 kJ

21. Assume each reaction is carried out in a open container. For which reaction will $\Delta H = \Delta E$? *(2006)*

a. $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$
b. $H_2(g) + Br_2(g) \rightarrow 2HBr(g)$
c. $C(s) + 2H_2O(g) \rightarrow 2H_2(g) + CO_2(g)$
d. $PCl_5(g) \rightarrow PCl_3(g) \rightarrow Cl_2(g)$

22. For the reaction:

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$ at constant temperature, $\Delta H - \Delta E$ is: *(2003)*

a. +RT
b. –3RT
c. +3RT
d. –RT

23. For the reaction $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$ which one is true? [MR*] *(2000)*

a. $\Delta H = \Delta E - RT$
b. $\Delta H = \Delta E + RT$
c. $\Delta H = \Delta E + 2RT$
d. $\Delta H = \Delta E - 2RT$

24. In an endothermic reaction, the value of ΔH is: *(1999)*

a. Zero
b. Positive
c. Negative
d. Constant

25. For the reaction $N_2 + 3H_2 \rightleftharpoons 2NH_3$, $\Delta H = ?$ *(1991)*

a. $\Delta E + 2RT$
b. $\Delta E - 2RT$
c. $\Delta H = RT$
d. $\Delta E - RT$

26. If ΔH is the change in enthalpy and ΔE, the change in internal energy accompanying a gaseous reaction, then: *(1990)*

a. ΔH is always greater than ΔE
b. $\Delta H < \Delta E$ only if the number of moles of the products is greater than the number of moles of the reactants
c. ΔH is always less than ΔE
d. $\Delta H < \Delta E$ only if the number of moles of products is less than the number of moles of the reactants.

Enthalpies For Different Types of Reactions

27. Consider the following reaction:- *(2023-Manipur)*

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)\Delta_r H° = -483.64$ kJ.

What is the enthalpy change for decomposition of one mole of water ? (Choose the **right** option).

a. 120.9 kJ
b. 241.82 kJ
c. 18 kJ
d. 100 kJ

28. At standard conditions, if the change in the enthalpy for the following reaction is –109 kJ mol^{-1}

$H_2(g) + Br_2(g) \rightarrow 2HBr(g)$

Given that bond energy of H_2 and Br_2 is 435 kJ mol^{-1} and 192 kJ mol^{-1}, respectively, what is the bond energy (in kJ mol^{-1}) of HBr? [MR*] *(2020-Covid)*

a. 736
b. 518
c. 259
d. 368

29. The bond dissociation energies of X_2, Y_2 and XY are in the ratio of 1 : 0.5 : 1. ΔH for the formation of XY is –200 kJ mol^{-1} *(2018)*

The bond dissociation energy of X_2 will be

a. 200 kJ mol^{-1}
b. 100 kJ mol^{-1}
c. 400 kJ mol^{-1}
d. 800 kJ mol^{-1}

30. The heat of combustion of carbon to CO_2 is –393.5 kJ/mol. The heat released upon formation of 35.2 g of CO_2 from carbon and oxygen gas is: [MR*] *(2015)*

a. + 315 kJ b. – 630 kJ
c. – 3.15 kJ d. – 315 kJ

31. Standard enthalpy of vaporisation ΔH_{vap} for water at 100°C is 40.66 kJ mol^{-1}. The internal energy of vaporisation of water at 100°C (in kJ mol^{-1}) is: *(2012 Pre)*

a. +40.66 b. +37.56
c. –43.76 d. +43.76

32. Enthalpy change for the reaction, $4H(g) \rightarrow 2H_2(g)$ is –869.6 kJ. The dissociation energy of H–H bond is: *(2011 Pre)*

a. +217.4 kJ b. –434.8 kJ
c. –869.6 kJ d. +434.8 kJ

33. From the following bond energies:

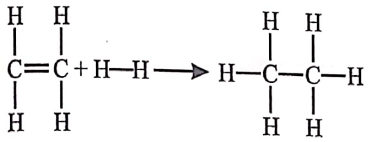
H – H bond energy: 431.37 kJ mol^{-1}

C = C bond energy: 606.10 kJ mol^{-1}

C – C bond energy: 336.49 kJ mol^{-1}

C – H bond energy: 410.50 kJ mol^{-1}

Enthalpy for the reaction,



will be: *(2009)*

a. –243.6 kJmol^{-1} b. –120.0 kJmol^{-1}
c. –553.0 kJmol^{-1} d. –1523.6 kJmol^{-1}

34. Bond dissociation enthalpy of H_2, Cl_2 and HCl are 434, 242 and 431 kJmol^{-1} respectively. Enthalpy of formation of HCl is: [MR*] *(2008)*

a. 245 kJmol^{-1} b. 93 kJmol^{-1}
c. –245 kJmol^{-1} d. –93 kJmol^{-1}

35. Given that bond energies of H – H and Cl – Cl are 430 kJ mol^{-1} and 240 kJ mol^{-1} respectively and ΔH_f for HCl is – 90 kJ mol^{-1}, bond enthalpy of HCl is: *(2007)*

a. 380 kJ mol^{-1} b. 425 kJ mol^{-1}
c. 245 kJ mol^{-1} d. 290 kJ mol^{-1}

36. Consider the following reactions:

(i) $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

$\Delta H = -X_1$ kJ mol^{-1}

(ii) $H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(l)$,

$\Delta H = -X_2$ kJ mol^{-1}

(iii) $CO_2(g) + H_2(g) \rightarrow CO(g) + H_2O$,

$\Delta H = -X_3$ kJ mol^{-1}

(iv) $C_2H_2(g) + \frac{5}{2}O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$,

$\Delta H = -X_4$ kJ mol^{-1}

Enthalpy of formation of H_2O (l) is: *(2007)*

a. $+X_3$ kJ mol^{-1} b. $-X_4$ kJ mol^{-1}
c. $+X_1$ kJ mol^{-1} d. $-X_2$ kJ mol^{-1}

37. The enthalpy of hydrogenation of cyclohexene is –119.5 kJ mol^{-1}. If resonance energy of benzene is –150.4 kJ mol^{-1}, its enthalpy of hydrogenation would be: *(2006)*

a. – 358.5 kJ mol^{-1} b. – 508.9 kJ mol^{-1}
c. – 208.1 kJ mol^{-1} d. – 269.9 kJ mol^{-1}

38. The absolute enthalpy of neutralisation of the reaction: $MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$ will be: *(2005)*

a. Less than –57.33 kJ mol^{-1}

b. –57.33 kJ mol^{-1}

c. Greater than –57.33 kJ mol^{-1}

d. 57.33 kJ mol^{-1}

39. If the bond energies of H – H, Br – Br and H – Br are 433,192 and 364 kJ mol^{-1} respectively, the ΔH^0 for the reaction *(2004)*

$H_2(g) + Br_2(g) \rightarrow 2HBr(g)$ is:

a. + 103 kJ b. + 261 kJ
c. – 103 kJ d. – 261 kJ

40. For which one of the following equations is $\Delta H_{reaction}$ equal to ΔH°_f for the product: [MR*] *(2003)*

a. $N_2(g) + O_3(g) \rightarrow N_2O_3(g)$

b. $CH_4(g) + 2Cl_2(g) \rightarrow CH_2Cl_2(l) + 2HCl(g)$

c. $Xe(g) + 2F_2(g) \rightarrow XeF_4(g)$

d. $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$

41. Heat of combustion ΔH° for C(s), $H_2(g)$ and $CH_4(g)$ are – 94, – 68 and – 213 kcal/mol, then ΔH° for C (s) + $2H_2$ (g) $\rightarrow CH_4(g)$ is: *(2002)*

a. –17 kcal b. –111 kcal
c. –170 kcal d. –85 kcal

42. Change in enthalpy for reaction

$2H_2O_2(\ell) \rightarrow 2H_2O(\ell) + O_2(g)$

If heat of formation of $H_2O_2(\ell)$ and $H_2O(\ell)$ are –188 and –286 KJ/mol respectively: *(2001)*

a. –196 kJ/mol b. +196 kJ/mol
c. +948 kJ/mol d. –948 kJ/mol

43. Enthalpy of $CH_4 + \frac{1}{2}O_2 \rightarrow CH_3OH$ is negative. If enthalpy of combustion of CH_4 and CH_3OH are x and y respectively. Then which relation is correct? *(2001)*

a. x > y b. x < y
c. x = y d. x ≥ y

44. In the reaction

$S(s) + \frac{3}{2}O_2(g) \rightarrow SO_3(g) + 2x$ kcal

and $SO_2(g) + \frac{1}{2}O_2(g) \rightarrow SO_3(s) + y$ kcal

the heat of formation of SO_2 is: *(1999)*

a. (x + y) b. (x – y)
c. (2x + y) d. (2x – y)

45. Given that $C + O_2 \rightarrow CO_2$, $\Delta H^\circ = -x$ kJ

$2CO + O_2 \rightarrow 2CO_2$ $\Delta H^\circ = -y$ kJ

The enthalpy of formation of carbon monoxide will be: *(1997)*

a. $\frac{y-2x}{2}$ b. $2x-y$

c. $y-2x$ d. $\frac{2x-y}{2}$

46. If enthalpies of formation for $C_2H_4(g)$, $CO_2(g)$ and $H_2O(l)$ at 25°C and 1 atm pressure are 52, –394 and –286 kJ/mol respectively, then enthalpy of combustion of $C_2H_4(g)$ will be: *(1995)*

a. + 141.2 kJ/mol b. + 1412 kJ/mol

c. – 141.2 kJ/mol d. – 1412 kJ/mol

Spontaneity, Entropy, Gibbs Energy Change and Equilibrium

47. For irreversible expansion of an ideal gas under isothermal condition, the correct option is: *(2021)*

a. $\Delta U \neq 0, \Delta S_{total} \neq 0$ b. $\Delta U = 0, \Delta S_{total} \neq 0$

c. $\Delta U \neq 0, \Delta S_{total} = 0$ d. $\Delta U = 0, \Delta S_{total} = 0$

48. For the reaction, $2Cl(g) \rightarrow Cl_2(g)$, the correct option is: *(2020)*

a. $\Delta_r H > 0$ and $\Delta_r S < 0$ b. $\Delta_r H < 0$ and $\Delta_r S < 0$

c. $\Delta_r H < 0$ and $\Delta_r S < 0$ d. $\Delta_r H > 0$ and $\Delta_r S > 0$

49. If for a certain reaction $\Delta_r H$ is 30 kJ mol^{-1} at 450 K, the value of $\Delta_r S$ (in JK^{-1} mol^{-1}) for which the same reaction will be spontaneous at the same temperature is *(2020-Covid)*

a. –33 b. 33

c. –70 d. 70

50. In which case change in entropy is negative? *(2019)*

a. Evaporation of water

b. Expansion of a gas at constant temperature

c. Sublimation of solid to gas

d. $2H(g) \rightarrow H_2(g)$

51. For a given reaction, $\Delta H = 35.5$ KJ mol^{-1} and $\Delta S = 83.6$ JK^{-1} mol^{-1}. The reaction is spontaneous at: (Assume that ΔH and ΔS do not vary with temperature) *(2017-Delhi)*

a. $T > 298$ K b. $T < 425$ K

c. $T > 425$ K d. All temperatures

52. For a sample of perfect gas when its pressure is changed isothermally from P_i to P_f, the entropy change is given by: *(2016 - II)*

a. $\Delta S = nRT \ln\left(\frac{P_f}{P_i}\right)$ b. $\Delta S = nRT \ln\left(\frac{P_i}{P_f}\right)$

c. $\Delta S = nR \ln\left(\frac{P_f}{P_i}\right)$ d. $\Delta S = nR \ln\left(\frac{P_i}{P_f}\right)$

53. The correct thermodynamic conditions for the spontaneous reaction at all temperatures is: *(2016 - I)*

a. $\Delta H < 0$ and $\Delta S < 0$ b. $\Delta H < 0$ and $\Delta S = 0$

c. $\Delta H > 0$ and $\Delta S < 0$ d. $\Delta H < 0$ and $\Delta S > 0$

54. For the reaction, $X_2O_4(l) \rightarrow 2XO_2(g)$, $\Delta U = 2.1$ kcal, $\Delta S = 20$ cal K^{-1} at 300 K. Hence, ΔG is: *(2014)*

a. –2.7 kcal b. 9.3 kcal

c. –9.3 kcal d. 2.7 kcal

55. In which of the following reactions, standard reaction entropy change (ΔS°) is positive and standard Gibb's energy change (ΔG°) decreases sharply with increasing temperature? [MR*] *(2012 Pre)*

a. $\frac{1}{2}C\,(graphite) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$

b. $C\,(graphite) + \frac{1}{2}O_2(g) \rightarrow CO(g)$

c. $CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$

d. $Mg(s) + \frac{1}{2}O_2(g) \rightarrow MgO(s)$

56. The enthalpy of fusion of water is 1.435 kcal/mol. The molar entropy change for the melting of ice at 0°C: *(2012 Pre)*

a. 0.526 cal/mol K b. 10.52 cal/mol K

c. 21.04 cal/mol K d. 5.260 cal/mol K

57. If the enthalpy change for the transition of liquid water to steam is 30 kJ mol^{-1} at 27°C, the entropy change for the process would be: *(2011 Pre)*

a. 100 J mol^{-1} K^{-1} b. 10 J mol^{-1} K^{-1}

c. 1.0 J mol^{-1} K^{-1} d. 0.1 J mol^{-1} K^{-1}

58. For vaporisation of water at 1 atmospheric pressure, the values of ΔH and ΔS are 40.63 kJ mol^{-1} and 108.8 $JK^{-1}mol^{-1}$ respectively. The temperature when Gibbs energy change (ΔG) for this transformation will be zero, is: *(2010 Main)*

a. 273.4 K b. 393.4 K

c. 373.4 K d. 293.4 K

59. Match List-I (Equations) with List-II (Type of process) and select the correct option: [MR*] *(2010 Main)*

	List-I Equations		List-II Type of processes
A.	$K_p > Q$	(i)	Non-spontaneous
B.	$\Delta G^\circ < RT \ln Q$	(ii)	Equilibrium
C.	$K_p = Q$	(iii)	Spontaneous and endothermi
D.	$T > \frac{\Delta H}{\Delta S}$	(iv)	Spontaneous

a. A-(i) B-(ii) C-(iii) D-(iv)

b. A-(iii) B-(iv) C-(ii) D-(i)

c. A-(iv) B-(i) C-(ii) D-(iii)

d. A-(ii) B-(i) C-(iv) D-(iii)

60. Standard entropies of X_2, Y_2 and XY_3 are 60, 40 and 50 $JK^{-1}mol^{-1}$ respectively. For the reaction $\frac{1}{2}X_2+\frac{3}{2}Y_2 \rightleftharpoons XY_3, \Delta H=-30\ kJ\ mol^{-1}$ to be at equilibrium, the temperature should be: [MR*] *(2010 Pre)*

a. 500 K b. 750 K
c. 1000 K d. 1250 K

61. The values of ΔH and ΔS for the reaction, $C_{(graphite)} + CO_{2\,(g)} \rightarrow 2CO_{(g)}$ are 170 kJ and 170 JK^{-1}, respectively. This reaction will be spontaneous at: *(2009)*

a. 910 K b. 1110 K
c. 510 K d. 710 K

62. For the gas phase reaction, $PCl_5(g) \rightleftharpoons PCl_3(g)+Cl_2(g)$, Which of the following conditions is correct? *(2008)*

a. $\Delta H > 0$ and $\Delta S < 0$ b. $\Delta H = 0$ and $\Delta S < 0$
c. $\Delta H > 0$ and $\Delta S > 0$ d. $\Delta H < 0$ and $\Delta S < 0$

63. The enthalpy and entropy change for the reaction: $Br_2(l) + Cl_2(g) \rightarrow 2BrCl(g)$ are 30 $kJmol^{-1}$ and 105 $JK^{-1}\ mol^{-1}$ respectively. The temperature at which the reaction will be in equilibrium is: *(2006)*

a. 285.7 K b. 373 K
c. 250 K d. 400 K

64. Identify the correct statement for change of Gibb's energy for a system (ΔG_{system}) at constant temperature and pressure. *(2006)*

a. If $\Delta G_{system} < 0$, the process is not spontaneous
b. If $\Delta G_{system} > 0$, the process is spontaneous
c. If $\Delta G_{system} = 0$, the system has attained equilibrium
d. If $\Delta G_{system} = 0$, then system is still moving in a particular direction

65. Which of the following pairs of a chemical reaction is certain to result in a spontaneous reaction? *(2005)*

a. Exothermic and decreasing disorder
b. Endothermic and increasing disorder
c. Exothermic and increasing disorder
d. Endothermic and decreasing disorder

66. A reaction occurs spontaneously if: [MR*] *(2005)*

a. $T\Delta S < \Delta H$ and both ΔH and ΔS are +ve
b. $T\Delta S > \Delta H$ and both ΔH and ΔS are +ve
c. $T\Delta S = \Delta H$ and both ΔH and ΔS are +ve
d. $T\Delta S > \Delta H$ and ΔH is + ve and ΔS is –ve

67. Considering entropy (S) as a thermodynamic parameter, the criterion for the spontaneity of any process is:- *(2004)*

a. $\Delta S_{system} - \Delta S_{surroundings} > 0$ b. $\Delta S_{System} > 0$ only
c. $\Delta S_{surroundings} > 0$ only d. $\Delta S_{system} + \Delta S_{surroundings} > 0$

68. Standard enthalpy and standard entropy changes for the oxidation of ammonia at 298 K are – 382.64 kJ mol^{-1} and –145.6 $JK^{-1}\ mol^{-1}$, respectively. Standard Gibbs energy change for the same reaction at 298 K is:- [MR*] *(2004)*

a. – 339.3 kJ mol^{-1} b. – 439.3 $kJmol^{-1}$
c. – 523.2 kJ mol^{-1} d. – 221.1 $kJmol^{-1}$

69. The densities of graphite and diamond at 298 K are 2.25 and 3.31 g cm^{-3}, respectively. If the standard free energy difference ($\Delta G°$) is equal to 1895 J mol^{-1}, the pressure at which graphite will be transformed into diamond at 298 K is: *(2003)*

a. 9.92×10^8 Pa b. 9.92×10^7 Pa
c. 9.92×10^6 Pa d. 9.92×10^5 Pa

70. What is the entropy change (in J K^{-1} mol^{-1}) when one mole of ice is converted into water at 0°C ? (The enthalpy change for the conversion of ice to liquid water is 6.0 KJ mol^{-1} at 0°C): *(2003)*

a. 20.13 b. 2.013
c. 2.198 d. 21.98

71. 2 mole of ideal gas at 27°C temperature is expanded reversibly from 2 litre to 20 litre Find entropy change (R = 2 cal/mol K): *(2002)*

a. 92.1 b. 0
c. 4 d. 9.2

72. Unit of entropy is: *(2002)*

a. $JK^{-1}\ mol^{-1}$ b. $J\ mol^{-1}$
c. $J^{-1}K^{-1}\ mol^{-1}$ d. $JK\ mol^{-1}$

73. Which reaction is not feasible? *(2002)*

a. $2KI + Br_2 \rightarrow 2KBr + I_2$
b. $2\ KBr + I_2 \rightarrow 2KI + Br_2$
c. $2\ KBr + Cl_2 \rightarrow 2KCl + Br_2$
d. $2H_2O + 2F_2 \rightarrow 4HF + O_2$

74. $PbO_2 \rightarrow PbO\ ;\ \Delta G_{298} < 0$
$SnO_2 \rightarrow SnO\ ;\ \Delta G_{298} > 0$
Most probable oxidation state of Pb and Sn will be: *(2001)*

a. Pb^{+4}, Sn^{+4} b. Pb^{+4}, Sn^{+2}
c. Pb^{+2}, Sn^{+2} d. Pb^{+2}, Sn^{+4}

75. $2Zn + O_2 \rightarrow 2ZnO\ ;\ \Delta G° = -616$ J
$2Zn + S_2 \rightarrow 2ZnS\ ;\ \Delta G° = -293$ J
$S_2 + 2O_2 \rightarrow 2SO_2\ ;\ \Delta G° = -408$ J
$\Delta G°$ for the following reaction is:
$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$ *(2000)*

a. –731 J b. –1317 J
c. –501 J d. + 731 J

76. At 27°C, latent heat of fusion of a compound is 2930 J/mol. Entropy change is: *(2000)*

a. 9.77 J/mol-K b. 10.77 J/mol-K
c. 9.07 J/mol-K d. 0.977 J/mol-K

77. Identify the correct statement regarding entropy: *(1998)*

a. At absolute zero temperature, entropy of a perfectly crystalline substance is taken to be zero
b. At absolute zero of temperature, the entropy of a perfectly crystalline substance is +ve
c. At absolute zero of temperature, the entropy of all crystalline substance is to be zero
d. At 0°C, the entropy of a perfectly crystalline substance is taken to be zero

78. For a reaction to occur spontaneously: *(1995)*

a. ΔH must be negative

b. ΔS must be negative

c. $(\Delta H - T\Delta S)$ must be negative

d. $(\Delta H + T\Delta S)$ must be negative

79. Following reaction occurring in an automobile $2C_8H_{18}(g) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$. The sign of ΔH, ΔS and ΔG would be: [MR*] *(1994)*

a. $-, +, +$

b. $+, +, -$

c. $+, -, +$

d. $-, +, -$

Clausius Clapeyron Equation

80. Consider the following liquid-vapour equilibrium. Liquid $\rightleftharpoons$ Vapour. Which of the following relation correct? *(2016)*

a. $\frac{d\ln P}{dT^2} = \frac{-\Delta H_v}{T^2}$

b. $\frac{d\ln P}{dT} = \frac{-\Delta H_v}{RT^2}$

c. $\frac{d\ln G}{dT^2} = \frac{\Delta H_v}{RT^2}$

d. $\frac{d\ln P}{dT} = \frac{-\Delta H_v}{RT}$

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Answer Key

1. (a)	**2.** (a)	**3.** (c)	**4.** (a)	**5.** (d)	**6.** (a)	**7.** (d)	**8.** (d)	**9.** (d)	**10.** (d)
11. (a)	**12.** (b)	**13.** (a)	**14.** (b)	**15.** (b)	**16.** (b)	**17.** (c)	**18.** (c)	**19.** (d)	**20.** (d)
21. (b)	**22.** (b)	**23.** (a)	**24.** (b)	**25.** (b)	**26.** (d)	**27.** (b)	**28.** (d)	**29.** (d)	**30.** (a)
31. (b)	**32.** (d)	**33.** (b)	**34.** (d)	**35.** (b)	**36.** (d)	**37.** (c)	**38.** (a)	**39.** (c)	**40.** (c)
41. (a)	**42.** (a)	**43.** (b)	**44.** (d)	**45.** (a)	**46.** (d)	**47.** (b)	**48.** (c)	**49.** (d)	**50.** (d)
51. (c)	**52.** (d)	**53.** (d)	**54.** (a)	**55.** (b)	**56.** (d)	**57.** (a)	**58.** (c)	**59.** (c)	**60.** (b)
61. (b)	**62.** (c)	**63.** (a)	**64.** (c)	**65.** (c)	**66.** (b)	**67.** (d)	**68.** (a)	**69.** (none)	**70.** (d)
71. (d)	**72.** (a)	**73.** (b)	**74.** (d)	**75.** (a)	**76.** (a)	**77.** (a)	**78.** (c)	**79.** (d)	**80.** (b)

Explanations

1. (a) Heat given to a system or by the system (q) and work done (w) on the system or by the system are path functions, as they depend on the initial and final position.

A state function is the property of the system whose value depends only on the state of the system and is independent of the path.

ΔU (Internal energy) = q + w. It is a state function since it is independent of the path followed.

ΔG (Gibbs Energy) = $\Delta H - T\Delta S$ is also a state function, since it is independent of the path followed.

Hence, among the given q and w are not state functions.

2. (a) ΔU for an isothermal expansion/compression of ideal gas is zero, since, internal energy is the function of temperature.

For isothermal process,

$\Delta T = 0$

$\therefore \quad \Delta U = 0$

3. (c) Work is basically the area under the curve in the pV diagram.

$w = -p\Delta V$

i.e., Work done is the product of pressure and change in volume. Therefore, the graph in which the coordinate of p and V will be the highest than other will be the case of maximum work done. By observing all the given graphs, we may conclude that the pressure and the change in volume of graph given in option (c) is the highest, therefore it has the maximum area under the curve and hence it represents the maximum work done.

4. (a) At constant volume as $q_v = C_v\Delta T = \Delta U$

At constant pressure as $q_p = C_p\Delta T = \Delta H$

The difference between C_p and C_v for an ideal gas is shown by:

For one mole of an ideal gas, $\Delta H = \Delta U + \Delta(PV)$

$= \Delta U + \Delta(RT)$

$= \Delta U + R\Delta T$

$\therefore \Delta H = \Delta U + R\Delta T$

On putting the values of ΔH and ΔU, we have

$C_p\Delta T = C_v\Delta T + R\Delta T$

$C_p = C_v + R$

$\boxed{C_p - C_v = R}$

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5. (d)

• For Free expansion, $P_{ext} = 0$

$\therefore w = -p_{ex}\Delta V = 0$; So, Work done = 0

• For adiabatic condition, q = 0

From first law of thermodynamics

$\Delta U = q + w$

$\therefore \Delta U = 0$

• Internal energy (U) of an ideal gas is a function of temperature

$\therefore$ If internal energy remains constant

$\therefore \Delta T = 0$

6. (a) Given, $p_{ext} = 2$ bar, $V_1 = 0.1$ L, $V_2 = 0.25$ L

$\therefore w_{irr} = -p_{ext}\Delta V$

$= -2$ bar $\times (0.25 - 0.1)$ L $[\because \Delta V = V_2 - V_1]$

$= -0.30$ L-bar

$= -0.30 \times 100$ J $\Rightarrow -30$ J $[\because 1$ L bar $= 100$ J$]$

7. (d) $\Delta U = q + w$

For adiabatic process, q = 0

$\therefore \Delta U = w = -p.\Delta V$

$= -2.5$ atm $\times (4.50 - 2.50)$ L $[\because \Delta V = V_2 - V_1]$

$= -2.5 \times 2$ L-atm $\Rightarrow -5 \times 101.3$ J

$[\because 1$ L atm $= 101.3$ J$]$

$= -506.5$ J $\Rightarrow -505$ J

8. (d) $C_P = \frac{5}{2}R$

$C_V = \frac{3}{2}R$

$\therefore \frac{C_P}{C_V} = \frac{5}{3} = 1.67$

9. (d) For free expansion of an ideal gas

q = 0, $\Delta T = 0$ and w = 0

10. (d) $\because$ The ideal gas expands spontaneously in vacuum,

$\therefore p_{ext} = 0$

As, $w = -p_{ext}\Delta V$

$\therefore$ work done = 0

11. (a) Given, $p_{ext} = 3$ atm,

$V_1 = 4$ dm^3 = 4L $[\because 1$ dm$^3 = 1$ L$]$

$V_2 = 6$ dm$^3 = 6$ L

$\because w = -p_{ext}\Delta V$

$= -3 \times (6 - 4) = -6$ L atm

$= -6 \times 101.32$ J $[\because 1$ L atm $= 101.32$ J$]$

$= -608$ J

12. (b) Molar heat capacity = 75 JK^{-1}mol^{-1}

For 18g of water = 1 mole = 75 JK^{-1}mol^{-1}

For 1 g of water $= \frac{75}{18}$ JK^{-1} mol^{-1}

$q = 1.0$ kJ $= 10^3$ J

$q = m.c.\Delta T$

$1000 = 100 \times \frac{75}{18} \times \Delta T$

$\Rightarrow \Delta T = \frac{1000 \times 18}{100 \times 75} = 2.4$ K

13. (a) $\Delta E = q + w$

As system is closed, q = 0 and work is done on the system

$\therefore w \neq 0$

Temperature increases and hence internal energy of the system increases.

$\Delta E \neq 0$

As, $\Delta E = q + w$

$\Delta E = w$ ($\because q = 0$)

$\therefore \Delta E = w \neq 0$

14. (b) Given, heat supplied (q) = 500 J

$\because$ Volume is constant

$\therefore \Delta V = 0$

As, $w = -p\,\Delta V$

$\therefore w = 0$ ($\because \Delta V = 0$)

According to first law of thermodynamics

$\Delta U = q + w$

$\Delta U = q + 0$ ($\because w = 0$)

$\therefore \Delta U = q = 500$ J

15. (b) Isothermal means temperature is constant.

At constant temperature, change in internal energy (ΔE) remains constant.

So, $\Delta E = 0$

16. (b) This is the mathematical relation of first law of thermodynamics. Here, ΔU = Change in internal energy; Δq = Heat absorbed by the system and w = Work done by the system.

17. (c) During isothermal expansion of an ideal gas, $\Delta T = 0$ and $\Delta E = 0$. Now we know, $H = E + PV$ $\therefore \Delta H = \Delta E + \Delta(PV)$

$\Delta H = \Delta E + \Delta(nRT)$ $\therefore \Delta H = \Delta E + nR\Delta T$;

$\therefore \Delta H = 0 + 0 = 0$ ($\because \Delta E = 0$ & $\Delta T = 0$)

18. (c) $\Delta H = \Delta U + \Delta n_g RT$

19. (d) According to the data given –

$\frac{1}{2}A \rightarrow B \quad \Delta H = +150$ ... (i)

$3B \rightarrow 2C + D \quad \Delta H = -125$ ... (ii)

$E + A \rightarrow 2D \quad \Delta H = +350$ ... (iii)

For $B + D \rightarrow E + 2C$

Eq. (ii) + 2 × Eq.(i) – eq. (iii)

$\Delta H = -125 + (2 \times 150) - 350$

$\Delta H = -175$ kJ

20. (d) $Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$ ... (i)

$\Delta H = -26.8$ kJ

$FeO(s) + CO(g) \rightarrow Fe(s) + CO_2(g)$ ... (ii)

$\Delta H = -16.5$ kJ

For, ΔH of $Fe_2O_3(s) + CO(g) \rightarrow 2FeO(s) + CO_2(g)$

Eq (1) $-2 \times$ Eq(2)

$= -26.8 - (2 \times -16.5) = +6.2$ kJ

21. (b) $\Delta H = \Delta E + \Delta n_g RT$

if Δn_g = zero then $\Delta H = \Delta E$

Δn_g for reaction, $H_2(g) + Br_2(g) \rightarrow 2HBr(g)$ is zero i.e.

$\Delta H = \Delta E$

22. (b) $C_3H_8(g) + 5O_2 \rightarrow 3CO_2(g) + 4H_2O$

$\Delta n_g = 3 - 6 = -3$

$\Delta H = \Delta E + P\Delta V$

or $\Delta H - \Delta E = P\Delta V$

$\Delta H - \Delta E = \Delta ngRT = -3RT$

23. (a) $\Delta H = \Delta E + P\Delta V$

also $PV = nRT$ (ideal gas equation)

or $P\Delta V = \Delta nRT$

Δn = change in number of gaseous moles

$\therefore \Delta H = \Delta E + \Delta nRT$

For the given reaction, $\Delta ng = 2 - 3 = -1$

$\therefore \Delta H = \Delta E - RT$

24. (b) For endothermic reaction

$E_R < E_P$

So, $\Delta H = E_P - E_R = +ve$

25. (b) For the given reaction,

$\Delta n_g = 2 - 4 = -2$

$\because \Delta H = \Delta E + \Delta n_g RT$

$\therefore \Delta H = \Delta E - 2RT$

26. (d) If $n_p < n_r$; $\Delta n_g = n_p - n_r = -ve$.

Hence, $\Delta H < \Delta E$.

27. (b) For decomposition of 1 mole of water:

$$H_2O(g) \rightarrow H_2(g) + \frac{1}{2}O_2(g) : \Delta H = +\frac{483.64}{2}$$

$\Delta H = +241.82$ kJ

28. (d) $H_2(g) + Br_2(g) \rightarrow 2HBr(g)$; $\Delta H = -109$ kJ mol^{-1}

ΔH = sum of bond energy of reactants - sum of bond energy of products

$\Delta H = (BE_{H-H}) + (BE_{Br-Br}) - 2(BE_{H-Br})$

$-109 = (435) + (192) - 2(BE_{H-Br})$

$BE_{H-Br} = 368$ kJ mol^{-1}

29. (d) The reaction for $\Delta_f H°(XY)$

$$\frac{1}{2}X_2(g) + \frac{1}{2}Y_2(g) \rightarrow XY(g)$$

Bond energies of X_2, Y_2 and XY are x, $\frac{x}{2}$, x respectively

($\because$ ratio given is 1 : 0.5 : 1)

$$\therefore \Delta H = \frac{1}{2}(BE)_{X-X} + \frac{1}{2}(BE)_{Y-Y} - (B.E)_{X-Y}$$

$$\therefore \Delta H = \left(\frac{x}{2} + \frac{x}{4}\right) - x = -200$$

On solving, we get

$$\Rightarrow -\frac{x}{4} = -200 \Rightarrow x = 800 \text{ kJ/mole}$$

30. (a) $C(s) + O_2 \rightarrow CO_2(g)$; $\Delta H = -393.5$ kJ/mole

When heat of combustion is given then

$\Delta H_r = H_R - H_P$

$= 0 - (-393.5)$

$= 393.5$ kJ/mole

So, heat of formation of $CO_2 = 393.5$ kJ/mole

Heat released on formation of 44 gm of $CO_2 = 393.5$ kJ

Heat released on formation of 35.2 gm of

$$CO_2 = \frac{393.5}{44} \times 35.2$$

$= 314.8 \Rightarrow = 315$ kJ

31. (b) $\Delta H°_{Vap}$ for water at 100°C = 40.66 kJ/mole

$= 40.66 \times 10^3$ J/mole

At 100°C / 373 K

$H_2O(\ell) \rightarrow H_2O(g)$

$\Delta n_g = 1$

We know that $\Delta H = \Delta E + \Delta n_g RT$

$\Delta E = \Delta H - \Delta n_g RT$

$\Delta E = (40.66 \times 10^3 J) - (1 \times 8.314 \times 373)$

($\because$ R = 8.314 J mol^{-1} K^{-1})

$\Delta E = 37559$J/mole = 37.56 kJ/mole ($\because$ 1 kJ = 10^3 J)

32. (d) $4H \rightarrow 2H_2$; $\Delta H = -869.6$ kJ

$2H_2 \rightarrow 4H$; $\Delta H = 869.6$ kJ

$H_2 \rightarrow 2H$

$\therefore$ For dissociation enthalpy of H—H $= \frac{869.6}{2} = 434.8$ kJ

33. (b) For the given reaction, enthalpy of reaction can be calculated as

$= \Sigma$B.E. (reactants) $- \Sigma$B.E. (Product)

$= [B.E._{(C=C)} + B.E._{(H-H)} + 4 \times B.E._{(C-H)}]$

$- [B.E._{(C-C)} + 6 \times B.E._{(C-H)}]$

$= [606.10 + 431.37 + 4 \times 410.50] - [336.49 + 6 \times 410.50]$

$= 2679.47 - 2799.49 = -120.02$ kJ mol^{-1}

34. (d) $\Delta H_{reaction} = \Sigma B.E \text{ of reactant} - \Sigma B.E \text{ of product}$

$B.E_{H-H} = 434 \text{ kJ mol}^{-1}$

$B.E_{Cl-Cl} = 242 \text{ kJ mol}^{-1}$

$B.E_{H-Cl} = 431 \text{ kJ mol}^{-1}$

$\because \frac{1}{2}H_2 + \frac{1}{2}Cl_2 \rightarrow HCl$

$\Delta H_{reaction} = \frac{1}{2}B.E_{H-H} + \frac{1}{2}B.E_{Cl-Cl} - B.E_{H-Cl}$

$= \frac{1}{2} \times 434 + \frac{1}{2} \times 242 - 431 = -93 \text{ kJ mol}^{-1}$

35. (b) $\frac{1}{2}H_2 + \frac{1}{2}Cl_2 \rightarrow HCl, \Delta_f H = -90 \text{ kJ mol}^{-1}$

$\Delta H = \Sigma B.E._{(reactants)} - \Sigma B.E._{(product)}$

$\Delta H = \frac{1}{2}\left[(B.E)_{H_2} + (B.E)_{Cl_2}\right] - (B.E)_{HCl}$

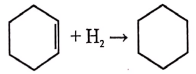
$-90 = \frac{1}{2}(430 + 240) - B.E_{HCl}$

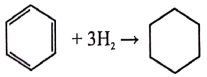
$\Rightarrow B.E_{HCl} = \frac{1}{2}(670) + 90$

$B.E_{HCl} = 335 + 90 = 425 \text{ kJ mol}^{-1}$

36. (d) $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l); \Delta H = -X_2 \text{ kJ mol}^{-1}$

This reaction shows the formation of H_2O, and the X_2 represents the enthalpy of formation of H_2O.

37. (c)  $\Delta H = -119.5$ kJ/mole



Enthalpy of hydrogenation of benzene

$= (3 \times \Delta H) - (\text{Resonance energy})$

$= [3 \times (-119.5)] - [-150.4] = -208.1 \text{ kJ/mole}$

38. (a) Heat of neutralization of strong acid and strong base is –57.33 kJ.

MgO is weak base while HCl is strong acid so heat of neutralization of MgO and HCl is lower to –57.33 kJ because MgO require some heat in ionisation, hence the net released amount of heat is decreased.

39. (c) $H_2 + Br_2 \rightarrow 2HBr$

$\Delta H = \Sigma B.E_{(reactants)} - \Sigma B.E_{(products)}$

$= [(B.E)_{H-H} + (B.E)_{Br-Br}] - [2 \times (B.E)_{H-Br}]$

$= (433 + 192) - (2 \times 364)$

$= -103 \text{ kJ}$

40. (c) For $H^\circ_{reaction} = \Delta H^\circ_F(XeF_4) - \left[\Delta H^\circ_F(Xe) + 2\Delta H^\circ_F(F_2)\right]$

Enthalpies of formation for elementary substances Xe and F_2 are taken as zero.

$H^\circ_{reaction} = \Delta H^\circ_F(XeF_4) - 0$

$\therefore H^\circ_{reaction} = \Delta H^\circ_F(XeF_4)$

41. (a) (i) $C(s) + O_2(g) \rightarrow CO_2(g)$

$\Delta H_i = -94 \text{ kcal mol}^{-1}$

(ii) $2H_2(g) + O_2(g) \rightarrow 2H_2O$

$\Delta H_{ii} = -68 \times 2 \text{ kcal mol}^{-1}$

(iii) $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O$

$\Delta H_{iii} = -213 \text{ kcalmol}^{-1}$

(iv) $C(s) + 2H_2(g) \rightarrow CH_4(g)$

$\Delta H_{iv} = ?$

Apply Hess's law

(i) + (ii) + reverse of (iii)

$= (-94 - 68 \times 2 + 213) \text{ kcal} \Rightarrow -17 \text{ kcal}$

42. (a) $\Delta H^0_f = \Sigma H^0_f(\text{product}) - \Sigma H^0_f(\text{reactant})$

For the given equation:

$2H_2O_2(\ell) \rightarrow 2H_2O(\ell) + O_2(g)$

$\Delta H^\circ_f = 2 \times \Delta H^\circ_f(H_2O) - 2 \times \Delta H^\circ_f(H_2O_2)$

($\because \Delta H^\circ_f(O_2) = 0$, elemental form)

$= 2 \times (-286 \text{ kJ mol}^{-1}) - 2 \times (-188) \text{ kJ mol}^{-1}$

$= -196 \text{ kJ mol}^{-1}$

43. (b) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O; \Delta H = x$ ...(i)

$CH_3OH + \frac{3}{2}O_2 \rightarrow CO_2 + 2H_2O; \Delta H = y$ ...(ii)

On subtracting eqn (ii) from (i), we get

$CH_4 + \frac{1}{2}O_2 \rightarrow CH_3OH$

$\therefore \Delta H = x - y$

Given ΔH = negative

Hence $x - y < 0$

$\therefore x < y$

44. (d) $S(s) + \frac{3}{2}O_2(g) \rightleftharpoons SO_3(g); \Delta H = +2x$ ...(i)

$SO_3(s) \rightleftharpoons SO_2(g) + \frac{1}{2}O_2; \Delta H = -y$ ...(ii)

On adding eq. (i) & (ii) we get

$S(s) + O_2(g) \rightleftharpoons SO_2(g); \Delta H = +(2x - y)$ kcal.

45. (a) $C(s) + O_2(g) \rightarrow CO_2(g); \Delta H = -x \text{ kJ}$ ...(i)

$CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g); \Delta H = -\frac{y}{2} \text{kJ}$ ...(ii)

By subtracting equation (ii) from (i) we get,

$\Delta H = -x - \left(-\frac{y}{2}\right) = \frac{y - 2x}{2} \text{ kJ}$

46. (d) $C_2H_4 + 3O_2 - \quad CO_2 + 2H_2O$

$\Delta_f H = \Delta_f H_{products} - \Delta_f H_{reactants}$

$= 2 \times (-394) + 2 \times (-286) - (52 + 0) = -1412 \text{ kJ/mol}$

47. (b) For isothermal (T = constant) expansion of an ideal gas into vacuum; $w = 0$ since $p_{ex} = 0$. ($\because w = -p\Delta V$)

$\Delta U = q + w$

For isothermal irreversible change $q = -w$

$\therefore \Delta U = -w + w$

$\Delta U = 0$

And for a spontaneous process, $\Delta S_{total} = \Delta S_{system} + \Delta S_{surr} > 0$ and irreversible process is always spontaneous, hence $\Delta S > 0$

48. (c) Given reaction, $2Cl(g) \rightarrow Cl_2(g)$

The reaction is exothermic since a bond is being formed in the given reaction, i.e., ΔH is −ve. So $\Delta_r H < 0$ and entropy is decreasing (−ve) in the reaction as number of molecules are decreasing which reduces the randomness of the system. thus, $\Delta_r S < 0$

49. (d) For spontaneous reaction, $\Delta_r G$ must be less than zero

So, $\Delta_r G = \Delta_r H - T\Delta_r S < 0$

$$\Delta_r H < T\Delta_r S \Rightarrow \frac{\Delta_r H}{T} < \Delta_r S$$

$$\text{or, } \Delta_r S > \frac{\Delta_r H}{T}$$

Given, $\Delta_r H = 30$ kJ mol^{-1}, $T = 450$ K

$$\therefore \Delta_r S > \frac{30{,}000}{450} = 66.67 JK^{-1}mol^{-1} \quad (\because 1 kJ = 1000 J)$$

For reaction to be spontaneous, the value of $\Delta_r S$ must be greater than 66.67 JK^{-1} mol^{-1} that is 70 JK^{-1} mol^{-1} (according to options).

50. (d) (a) During evaporation of water, the state of water gets changed from liquid to gas. The gaseous molecules have higher tendency to move and hence there will be more randomness. Thus, the entropy increases. Hence, the change in entropy (ΔS) > 0.

(b) If gas is expanding at constant temperature, then the volume will increase and the constituent particles move more freely and hence, the entropy increases due to increase in randomness. Therefore, $\Delta S > 0$.

(c) During sublimation process, solid gets converted into gaseous state, therefore randomness increases and hence entropy increases. Therefore, $\Delta S > 0$.

(d) $2H(g) \rightarrow H_2(g)$

$\Delta n_g = 1 - 2 = -1$

i.e., there is decrease in number of gaseous particles from reactant to product side, therefore randomness decreases and hence entropy decreases.

i.e., $\Delta S < 0$ as $\Delta n_g < 0$.

51. (c) As, $\Delta G = \Delta H - T\Delta S$

where, ΔG = Gibbs energy change

ΔH = Enthalpy change

ΔS = Entropy change

T = Temperature

For the reaction to be spontaneous, ΔG must be negative.

i.e., $\Delta G < 0$

$\therefore \Delta H - T\Delta S < 0 \quad (\because \Delta G = \Delta H - T\Delta S)$

$\Rightarrow \Delta H < T\Delta S$

$$\text{i.e, } T > \frac{\Delta H}{\Delta S}$$

Given, $\Delta H = 35.5$ kJ mol^{-1} $= 35.5 \times 10^3$ J mol^{-1}

$\Delta S = 83.6$ JK^{-1}

$$\therefore T > \frac{\Delta H}{\Delta S} = \frac{35.5 \times 10^3 J\ mol^{-1}}{83.6\ J\ mol^{-1}K^{-1}}$$

$T > 425$ K

52. (d) As, $\Delta S = \frac{q_{rev}}{T}$

For reversible isothermal process,

$$q_{rev} = -w = nRT \ln \frac{V_f}{V_i} \quad \cdots (i)$$

$$\left(\because w = -p\Delta V = \frac{-nRT}{V}\Delta V\right.$$

Now, using Charle's law: $P_iV_i = P_fV_f$

$$\Rightarrow \frac{P_i}{P_f} = \frac{V_f}{V_i} \quad \cdots (ii)$$

From equations (i) and (ii), we get.

$$q_{rev} = nRT \ln \frac{P_i}{P_f}$$

$$\therefore \Delta S = \frac{nRT \ln \frac{P_i}{P_f}}{T} \quad \left(\because \Delta S = \frac{q_{rev}}{T}\right)$$

$$\therefore \Delta S = nR \ln \frac{P_i}{P_f}$$

53. (d) For spontaneous process, ΔG must be negative

$\because \Delta G = \Delta H - T\Delta S$

$\therefore$ For making ΔG highly negative, the value of ΔH should be negative and the value of ΔS should be positive

$\therefore \Delta H < 0$ and $\Delta S > 0$

54. (a) As, $\Delta H = \Delta U + \Delta n_g RT$

where, Δn_g = No. of moles of gaseous products − No. of moles of gaseous reactants

For the given reaction, $\Delta n_g = 2$

$\Delta U = 2.1$ kcal $= 2.1 \times 10^3$ cal

As, $\Delta H = \Delta U + \Delta n_g RT$

$\therefore \Delta H = 2.1 \times 10^3 + 2 \times 2 \times 300 \quad (\because R = 2$ cal/mol-K)

$\Delta H = 3300$ cal

Now, $\Delta G = \Delta H - T\Delta S$

$= 3300 - (300 \times 20)$

$= 3300 - 6000$

$= -2700$ cal

$= -2.7$ kcal $\quad (\because 1$ cal $= 10^{-3}$ k cal)

55. (b) As C changes from solid to gas, randomness increases.

Therefore, entropy increases.

56. (d) $\Delta S_{syst.} = \frac{\Delta H}{T}$

$\Delta S = \frac{1.435 \times 10^3}{273} = 5.26$ cal/k mol. $[\because 0°C = 273\ K]$

57. (a) $\Delta S = \frac{\Delta H}{T}$

$T = 27°C = (27 + 273)K = 300\ K$

$\Delta S_{vap} = \frac{\Delta H_{vap}}{T} = \frac{30\ kJ\ mol^{-1}}{300\ K} = 100\ J\ mol^{-1}K^{-1}$

58. (c) $\Delta G = \Delta H - T\Delta S$

Gibbs free energy for transformation = 0

$T = \frac{\Delta H}{\Delta S}$

$\Delta T = \frac{40.63 \times 10^3}{108.8} = 373.4\ K$

59. (c) A → (iv) B → (i) C → (ii) D → (iii)

$K_p > Q \leftarrow$ Reaction moves in forward direction. i.e., reaction is spontaneous.

$\Delta G = \Delta G° + RT \ln Q$

If $[\Delta G° < RT \ln Q]$, then ΔG = (+ve) reaction becomes non spontaneous

$K_p = Q$ Reaction attains equilibrium

$T > \frac{\Delta H}{\Delta S} \Rightarrow \Delta H$ = (+ve) ⇒ endothermic reaction

When $\Delta H < T\Delta S$ reaction is spontaneous.

60. (b) $\Delta S° = \Sigma\Delta S_{products} - \Sigma\Delta S_{Reactants}$

$= 50 - \left[\frac{1}{2} \times 60 + \frac{3}{2} \times 40\right]$

$= 50 - (30 + 60)$

$\Delta S° = -40\ JK^{-1}\ mol^{-1}$

$\Delta G° = \Delta H° - T\Delta S°$, at equilibrium $\Delta G° = 0$

$T = \frac{\Delta H°}{\Delta S°} = \frac{-30 \times 10^3\ J\ mol^{-1}}{-40 \times JK^{-1}\ mol^{-1}} \Rightarrow 750K$

61. (b) For the reaction to be spontaneous, ΔG = –ve, Given, $\Delta H = 170\ kJ = 170 \times 10^3\ J$

$\Delta S = 170\ JK^{-1}\ mol^{-1}$

Applying, $\Delta G = \Delta H - T\Delta S$, the value of ΔG = –ve only when $T\Delta S > \Delta H$, which is possible only when T = 1110 K.

$\therefore \Delta G = 170 \times 10^3 - (1110 \times 170) = -18700\ J$

Thus, reaction is spontaneous at T = 1110 K

62. (c) $\Delta H = \Delta U + \Delta n_g RT$

$\Delta G = \Delta H - T\Delta S$

For spontaneous reaction, ΔG is – ve

$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

$\Delta n_g = 2 - 1 = 1$

Thus ΔH is + ve

If ΔH is +ve, then to maintain the value of ΔG to be –ve, ΔS should be +ve, i.e. $\Delta S > 0$

63. (a) According to 3rd Law of thermodynamics

$\Delta S = \frac{\Delta H}{T}$

$T = \frac{\Delta H}{\Delta S}$

$= \frac{30 \times 10^3\ J}{105} = 285.7\ K$

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64. (c) Criteria for spontaneity of a process in terms of ΔG is as following.

If ΔG = (–)ve ⇒ Process is spontaneous

If ΔG = (+)ve ⇒ Process is non-spontaneous.

If ΔG = zero ⇒ system is in equilibrium.

65. (c) For exothermic reaction ΔH is (–ve) and increasing disorderness or randomness increases the spontaneity of the reaction

$\Delta G = \Delta H - T\Delta S$

ΔG = –ve – (+ve × +ve) = –ve

So, ΔG is (–ve) negative.

66. (b) For spontaneous reaction, $\Delta G < 0$

$\Delta G = \Delta H - T\Delta S$

ΔG = (–ve) for spontaneous reaction

ΔS = (+ve), ΔH = (+ve)

$T\Delta S > \Delta H \Rightarrow \Delta G$ = (–ve)

67. (d) The total entropy change (ΔS_{total}) for the system and surroundings of a spontaneous process is given by

$\Delta S_{total} = \Delta S_{system} + \Delta S_{surr} > 0.$

68. (a) $\Delta G = \Delta H - T\Delta S$

$= -382.64 - 298\left(\frac{-145.6}{1000}\right) = -382.64 + 43.38$ $[\because 1\ J = 10^{-3}\ kJ]$

$= -339.3\ kJ\ mol^{-1}$

69. (None) $\Delta G = -p\Delta V$ = work done (w)

$\because$ density $= \frac{\text{mass}}{\text{Volume}}$

$\therefore V_{graphite} = \frac{12\ g}{2.25\ g/cm^3} = \frac{12}{2.25} cm^3$ $\left(\because \text{Volume} = \frac{\text{mass}}{\text{density}}\right)$

$V_{diamond} = \frac{12g}{3.31\ g/cm^3} = \frac{12}{3.31} cm^3$

$\therefore \Delta V = \left[\frac{12}{3.31} - \frac{12}{2.25}\right] cm^3 \times 10^{-3}$

$\Delta V = -1.71 \times 10^{-3}\ L$ $(\because 1\ cm^3 = 10^{-3}\ L)$

Now, $\Delta G = -p\Delta V$

$1895 = -p \times (-1.71 \times 10^{-3})$ L-atm

$1895 = -p \times (-1.71 \times 10^{-3}) \times 101.3$ J

($\because$ 1 L-atm = 101.3 J)

$$\therefore p = \frac{1895}{1.71\times10^{-3}\times101.3} = 10.93\times10^{3} \text{ atm}$$

$\therefore p = 10.93 \times 10^3 \times 1.01 \times 10^5$ Pa

($\because$ 1 atm = 1.01×10^5 Pa)

$\Rightarrow p = 11.07 \times 10^8$ Pa

Hence, none of the given options is correct.

70. (d) Given, q = 6.0 kJ mol^{-1} = 6.0×10^3 J mol^{-1}, and T = 0°C = 273 K

$$S = \frac{q_{rev}}{T} = \frac{6000}{273} = 21.978 \text{ J/K}$$

71. (d) Given, n = 2 moles, T = 27°C = (27 + 273)K = 300 K

$V_1 = 2L$, $V_2 = 20$ L, R = 2 cal/mol K

$$\because \Delta S = \frac{q}{T} = \frac{-w}{T} = -\frac{\left(-2.303nRT\log\frac{V_2}{V_1}\right)}{T}$$

$$\therefore \Delta S = 2.303 \text{ nR} \log \frac{V_2}{V_1}$$

$$= 2.303\times2\times2\times\log\frac{20}{2}$$

$= 2.303 \times 4 \times \log 10$

$= 9.212$ cal/mol – K

72. (a) Entropy $(S) = \frac{q}{T} = \frac{J\ mol^{-1}}{K} = JK^{-1}\ mol^{-1}$

73. (b) $2KBr + I_2 \rightarrow 2KI + Br_2$

As electronegative character decreases down the group, so option (b) is not feasible.

74. (d) The sign and magnitude of Gibbs energy is a criterion of spontaneity for a process. When $\Delta G > 0$ or +ve, it means $G_{product} > G_{reactant}$, as $\Delta G = G_{product} - G_{reactant}$ the reaction will not take place spontaneously, i.e. the reaction should be spontaneous in reverse direction.

$$\underset{+4}{SnO_2} \longrightarrow \underset{+2}{SnO};\ \Delta G > 0$$

(more favourable)

$\Delta G < 0$ or –ve, the reaction or change occurs spontaneously,

$PbO_2 \rightarrow PbO;\ \Delta G < 0$

+4 +2

(more favourable)

75. (a) For the reactions,

$2ZnS \rightarrow 2Zn + S_2;\ \Delta G^\circ = +293$ J ...(i)

$2Zn + O_2 \rightarrow 2ZnO;\ \Delta G^\circ = -616$ J ...(ii)

$S_2 + 2O_2 \rightarrow 2SO_2;\ \Delta G^\circ = -408$ ...(iii)

Then ΔG° for the reaction,

$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$ can be obtained by adding eq. (i), (ii) and (iii)

So, $\Delta G^\circ = 293 - 616 - 408 = -731$ J

76. (a) $\Delta S = \frac{Q}{T} = \frac{2930}{300} = 9.77$ J/mol K

77. (a) At absolute zero temperature, entropy of a perfectly crystalline substance is taken to be zero. It is called third law of thermodynamics

78. (c) For a reaction to be spontaneous, ΔG (Gibbs free energy change) must be negative.

$\Delta G = \Delta H - T\Delta S$

ΔH = change in enthalpy, ΔS = change in entropy.

Hence, $\Delta H - T\Delta S$ must be –ve for a spontaneous reaction.

79. (d) (i) The given reaction is a combustion reaction, therefore ΔH is less than 0 because heat is released. Hence, ΔH is negative.

(ii) Since there is increase in the number of moles, therefore ΔS is positive

(iii) Since reaction is spontaneous, therefore ΔG is negative.

80. (b) $\frac{dlnP}{dT} = \frac{-\Delta H_v}{RT^2}$ (this is Clausius Clapeyron equation.)

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CHAPTER 6

Equilibrium

Law of Chemical Equilibrium, Equilibrium Const. and Its Application

1. K_p for the following reaction is 3.0 at 1000 K. *(2022 Re)*

$CO_2(g) + C(s) \rightleftharpoons 2CO(g)$

What will be the value of Kc for the reaction at the same temperature?

(Given – R = 0.083 L bar K^{-1} mol^{-1})

a. 3.6 b. 0.36

c. 3.6×10^{-2} d. 3.6×10^{-3}

2. $3O_2(g) \rightleftharpoons 2O_3(g)$ for the given reaction at 298 K, K_c is found to be 3.0×10^{-59}. If the concentration of O_2 at equilibrium is 0.040 M, then concentration of O_3 in M is: *(2022)*

a. 1.2×10^{21} b. 4.38×10^{-32}

c. 1.9×10^{-63} d. 2.4×10^{31}

3. The equilibrium constants of the following are:

$N_2 + 3H_2 \rightleftharpoons 2NH_3$ K_1

$N_2 + O_2 \rightleftharpoons 2NO$ K_2

$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$ K_3

The equilibrium constant (K) of the reaction:

[**MR***] *(2017-Delhi)*

$2NH_3 + \frac{5}{2}O_2 \overset{K}{\rightleftharpoons} 2NO + 3H_2O$, will be:

a. $K_2^3K_3/K_1$ b. $K_1K_3^3/K_2$

c. $K_2K_3^3/K_1$ d. K_2K_3/K_1

4. If the equilibrium constant for

$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ is K, the equilibrium constant for

$\frac{1}{2}N_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons NO(g)$ will be: *(2015 Re)*

a. K^2 b. $K^{1/2}$

c. $\frac{1}{2}K$ d. K

5. If the value of an equilibrium constant for a particular reaction is 1.6×10^{12}, then at equilibrium the system will contain: *(2015)*

a. Mostly reactants

b. Mostly products

c. Similar amounts of reactants and products

d. All reactants

6. Given the reaction between 2 gases represented by A_2 and B_2 to give the compound AB (g).

$A_2(g) + B_2(g) \rightleftharpoons 2AB(g)$. At equilibrium, the concentration of $A_2 = 3.0 \times 10^{-3}$ M of $B_2 = 4.2 \times 10^{-3}$ M of AB = 2.8×10^{-3} M. If the reaction takes place in a sealed vessel at 527°C, then the value of K_c will be: [**MR***] *(2012 Mains)*

a. 4.5 b. 2.0

c. 1.9 d. 0.62

7. Given that the equilibrium constant for the reaction $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ has a value of 278 at a particular temperature. What is the value of the equilibrium constant for the following reaction at the same temperature?

(2012 Mains)

$SO_3(g) \rightleftharpoons SO_2(g) + \frac{1}{2}O_2(g)$

a. 1.3×10^{-5} b. 1.8×10^{-3}

c. 3.6×10^{-3} d. 6.0×10^{-2}

8. For the reaction: $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$, the equilibrium constant is K_1. The equilibrium constant is K_2 for the reaction: $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$. What is K for the reaction:

(2011 Pre)

$NO(g) \rightleftharpoons \frac{1}{2}N_2(g) + O_2(g)$?

a. $\frac{1}{(K_1K_2)}$ b. $\frac{1}{(2K_1K_2)}$

c. $\frac{1}{(4K_1K_2)}$ d. $\left[\frac{1}{K_1K_2}\right]^{1/2}$

9. The reaction $2A(g) + B(g) \rightleftharpoons 3C(g) + D(g)$ is begun with the concentrations of A and B both at an initial value of 1.00 M. When equilibrium is reached, the concentration of D is measured and found to be 0.25 M. The value for the equilibrium constant for this reaction is given by the expression: *(2010 Mains)*

a. $[(0.75)^3(0.25)] \div [(1.00)^2(1.00)]$

b. $[(0.75)^3(0.25)] \div [(0.50)^2(0.75)]$

c. $[(0.75)^3(0.25)] \div [(0.50)^2(0.25)]$

d. $[(0.75)^3(0.25)] \div [(0.75)^2(0.25)]$

10. In which of the following equilibrium, K_c and K_p are not equal? **[MR*]** *(2010 Pre)*

a. $2C(s) + O_2(g) \rightleftharpoons 2CO_2(g)$

b. $2NO(g) \rightleftharpoons N_2(g) + O_2(g)$

c. $SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g)$

d. $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

11. The value of equilibrium constant of the reaction

$HI(g) \rightleftharpoons \frac{1}{2}H_2(g) + \frac{1}{2}I_2(g)$ is 8.0

The equilibrium constant of the reaction

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ will be: *(2008)*

a. $\frac{1}{8}$ b. $\frac{1}{16}$

c. $\frac{1}{64}$ d. 16

12. The following equilibrium constants are given:

$N_2 + 3H_2 \rightleftharpoons 2NH_3$; K_1

$N_2 + O_2 \rightleftharpoons 2NO$; K_2

$H_2 + \frac{1}{2}O_2 \rightleftharpoons H_2O$; K_3

The equilibrium constant for the oxidation of NH_3 by oxygen to give NO is? *(2007)*

a. $\frac{K_2K_3^2}{K_1}$ b. $\frac{K_2^2K_3}{K_1}$

c. $\frac{K_1K_2}{K_3}$ d. $\frac{K_2K_3^3}{K_1}$

13. Equilibrium constants K_1 and K_2 for the following equilibria: *(2005)*

$NO(g) + (1/2)O_2 \xrightleftharpoons{K_1} NO_2(g)$ and $2NO_2(g)$

$2NO_2(g) \xrightleftharpoons{K_2} 2NO(g) + O_2(g)$ are related as:

a. $K_2 = 1/K_1$ b. $K_2 = K_1^2$

c. $K_2 = K_1/2$ d. $K_2 = 1/K_1^2$

14. The reaction quotient (Q) for the reaction:

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ is given by $Q = \frac{[NH_3]^2}{[N_2][H_2]^3}$

The reaction will proceed from right to left if: *(2003)*

a. $Q = K_c$ b. $Q < K_c$

c. $Q > K_c$ d. $Q = 0$

(Where K_c is the equilibrium constant)

15. The following equilibrium are given:

$N_2 + 3H \rightleftharpoons 2NH_3$; K_1

$N_2 + O_2 \rightleftharpoons 2NO$; K_2

$H_2 + \frac{1}{2}O_2 \rightleftharpoons H_2O$; K_3

The equilibrium constant of the reaction

$2NH_3 + \frac{5}{2}O_2 \rightleftharpoons 2NO + 3H_2O$ in terms of K_1, *(2003)*

a. $K_1K_2K_3$ b. $\frac{K_1K_2}{K_3}$

c. $\frac{K_1K_3^2}{K_2}$ d. $\frac{K_2K_3^3}{K_1}$

16. Equilibrium constant K_p for following reaction: *(2000)*

$MgCO_3(s) \rightleftharpoons MgO(s) + CO_2(g)$

a. $K_p = p_{CO_2}$ b. $K_p = p_{CO_2} \times \frac{p_{CO_2} \times p_{MgO}}{p_{MgCO_3}}$

c. $K_p = \frac{p_{CO_2} \times p_{MgO}}{p_{MgCO_3}}$ d. $K_p = \frac{p_{MgCO_3}}{p_{CO_2} \times p_{MgO}}$

17. If K_1 and K_2 are the respective equilibrium constants for the two reactions:

$XeF_6(g) + H_2O(g) \rightleftharpoons XeOF_4(g) + 2HF(g)$

$XeO_4(g) + XeF_6(g) \rightleftharpoons XeOF_4(g) + XeO_3F_2(g)$

the equilibrium constant of the reaction

$XeO_4(g) + 2HF(g) \rightleftharpoons XeO_3F_2(g) + H_2O(g)$

will be: **[MR*]** *(1998)*

a. $K_2/(K_2)^2$ b. $K_1 K_2$

c. K_1/K_2 d. K_2/K_1

18. The equilibrium constant for the reaction $N_2 + 3H_2 \rightleftharpoons 2NH_3$ is *K*, then the equilibrium constant for the reaction: $2NH_3 \rightleftharpoons N_2 + 3H_2$ is: *(1996)*

a. $\sqrt{K}$ b. $\sqrt{\frac{1}{K}}$

c. $\frac{1}{K}$ d. $\frac{1}{K^2}$

19. In liquid-gas equilibrium, the pressure of vapours above the liquid is constant at: *(1995)*

a. Constant temperature b. Low temperature

c. High temperature d. None of these

20. K_1 and K_2 are equilibrium constant for reactions (i) and (ii) *(1989)*

$N_2(g)+O_2(g) \rightleftharpoons 2NO(g)$ ...(i)

$NO(g) \rightleftharpoons \frac{1}{2}N_2(g)+\frac{1}{2}O_2(g)$ ...(ii)

a. $K_1=\left(\frac{1}{K_2}\right)^2$ b. $K_1=K_2^2$

c. $K_1=\frac{1}{K_2}$ d. $K_1=(K_2)^0$

Relation Between K,Q and G, Factors Affecting Equilibria

21. The equilibrium concentrations of the species in the reaction $A+B \rightleftharpoons C+D$ are 2, 3, 10 and 6 mol L^{-1} respectively at 300 K. ΔG^0 for the reaction is *(2023)*

(R = 2 cal/mol K)

a. –13.73 cal b. 1372.60 cal

c. –137.26 cal d. –1381.80 cal

22. Hydrolysis of sucrose is given by the following reaction:

Sucrose + $H_2O \rightleftharpoons$ Glucose + Fructose

If the equilibrium constant (K_c) is 2×10^{13} at 300 K, the value of $\Delta_r G^o$ at the same temperature will be : *(2020)*

a. 8.314 J mol^{-1} $K^{-1} \times 300$ K $\times$ ln (2×10^{13})

b. 8.314 J mol^{-1} $K^{-1} \times 300$ K $\times$ ln (3×10^{13})

c. –8.314 J mol^{-1} $K^{-1} \times 300$ K $\times$ ln (4×10^{13})

d. –8.314 J mol^{-1} $K^{-1} \times 300$ K $\times$ ln (2×10^{13})

23. Which one of the following conditions will favour maximum formation of the product in the reaction,

$A_2(g)+B_2(g) \rightleftharpoons X_2(g)\ \Delta_r H=-X$ kJ [**MR***] *(2018)*

a. Low temperature and high pressure

b. Low temperature and low pressure

c. High temperature and low pressure

d. High temperature and high pressure

24. Which one of the following statements is not correct? *(2017-Delhi)*

a. Coenzymes increase the catalytic activity of enzyme

b. Catalyst does not initiate any reaction

c. The value of equilibrium constant is changed in the presence of a catalyst in the reaction at equilibrium

d. Enzymes catalyse mainly bio-chemical reactions

25. A 20 litre container at 400 K contains $CO_2(g)$ at pressure 0.4 atm and an excess of SrO (neglect the volume of solid SrO). The volume of the containers is now decreased by moving the movable piston fitted in the container. The maximum volume of the container, when pressure of CO_2 attains its maximum value, will be: *(2017-Delhi)*

(Given that: $SrCO_3(s) \rightleftharpoons SrO(s)+CO_2(g)$ $K_p = 1.6$ atm)

a. 2 litre b. 5 litre

c. 10 litre d. 4 litre

26. Consider the nitration of benzene using mixed conc. H_2SO_4 and HNO_3. If a larger amount of $KHSO_4$ is added to the mixture, the rate of nitration will be: *(2016 - I)*

a. Doubled b. Increase

c. Decrease d. Unchanged

27. Which of the following statements is correct for a reversible process in a state of equilibrium? *(2015)*

a. $\Delta G^o = -2.303$ RT log K b. $\Delta G^o = 2.303$ RT log K

c. $\Delta G = -2.303$ RT log K d. $\Delta G = 2.303$ RT log K

28. For a given exothermic reaction, K_p and K'_p are the equilibrium constants at temperature T_1 and T_2, respectively. Assuming that heat of reaction is constant in temperature range between T_1 and T_2, it is readily observed that *(2014)*

a. $K_p > K'_p$ b. $K_p < K'_p$

c. $K_p = K'_p$ d. $K_p=\frac{1}{K'_p}$

29. For the reversible reaction,

$N_2(g)+3H_2(g) \rightleftharpoons 2NH_3(g)+$ Heat. The equilibrium shifts in forward direction: *(2014)*

a. By decreasing the pressure

b. By decreasing the concentrations of $N_2(g)$ and $H_2(g)$

c. By increasing pressure and decreasing temperature

d. By increasing the concentration of $NH_3(g)$

30. $KMnO_4$ can be prepared from K_2MnO_4 as per the reaction:

$3MnO_4^{2-}+2H_2O \rightleftharpoons 2MnO_4^- + MnO_2 + 4OH^-$

The reaction can go to completion by removing OH^- ions by adding: *(2013)*

a. HCl b. KOH

c. CO_2 d. SO_2

31. The value of ΔH for the reaction,

$X_2(g)+4Y_2(g) \rightleftharpoons 2XY_4(g)$ is less than zero. Formation of $XY_4(g)$ will be favored at: *(2011 Pre)*

a. High pressure and low temperature

b. High temperature and high pressure

c. Low pressure and low temperature

d. High temperature and low pressure

32. If the concentration of OH^- ions in the reaction

$Fe(OH)_3(s) \rightleftharpoons Fe^{3+}(aq)+3OH^-(aq)$ is decreased by $\frac{1}{4}$ times, then equilibrium concentration of Fe^{3+} will increase by: *(2008)*

a. 4 times b. 8 times

c. 16 times d. 64 times

33. For the reaction,

$CH_4(g)+2O_2(g) \rightleftharpoons CO_2(g)+2H_2O(l)$,

$\Delta_r H = -170.8$ kJmol^{-1}. Which of the following statements is not true? [**MR***] *(2006)*

a. At equilibrium, the concentrations of CO_2 (g) and H_2O (l) are not equal

b. The equilibrium constant for the reaction is given by $K_p = [CO_2]/[CH_4][O_2]$

c. Addition of $CH_4(g)$ or $O_2(g)$ at equilibrium will cause a shift to the right

d. The reaction is exothermic

34. Reaction

$BaO_2(s) \rightleftharpoons BaO(s) + O_2(g); \Delta H = +ve.$

In equilibrium condition, pressure of O_2 depends on: *(2002)*

a. Increase mass of BaO_2
b. Increase mass of BaO
c. Increase temp on equilibrium
d. Increase mass of BaO_2 and BaO both

35. For any reversible reaction, if we increase concentration of reactants, then effect on equilibrium constant: *(2000)*

a. Depends on amount of concentration
b. Unchange
c. Decrease
d. Increase

36. A chemical reaction is catalyzed by a catalyst X. Hence, X *(1995)*

a. Reduces enthalpy of the reaction
b. Does not affect equilibrium constant of reaction
c. Decreases rate constant of the reaction
d. Increases activation energy of the reaction.

37. Standard state Gibb's free energy change for isomerisation reaction *cis*-2-pentene $\rightleftharpoons$ *trans*- 2-pentene is –3.67 kJ/mol at 400 K. If more trans- 2-pentene is added to the reaction vessel, then: *(1995)*

a. Equilibrium remains unaffected
b. Equilibrium is shifted in the forward direction
c. More *cis*-2-pentene is formed
d. Additional *trans*-2-pentene is formed.

38. According to Le Chatelier's principle, adding heat to a solid and liquid in equilibrium will cause the: *(1993)*

a. Temperature to increase
b. Temperature to decrease
c. Amount of liquid to decrease
d. Amount of solid to decrease

39. Which one of the following information can be obtained on the basis of Le Chatelier principle? *(1992)*

a. Dissociation constant of a weak acid
b. Entropy change in a reaction
c. Equilibrium constant of a chemical reaction
d. Shift in equilibrium position on changing value of a concentration.

Acids, Bases and Salts

40. Conjugate base for Bronsted acids H_2O and HF are: **[MR*]** *(2019)*

a. OH^- and H_2F^+, respectively
b. H_3O^+ and F^-, respectively
c. OH^- and F^-, respectively
d. H_3O^+ and H_2F^+, respectively

41. Which of the following fluoro-compounds is most likely to behave as a Lewis base? *(2016 - II)*

a. CF_4 b. SiF_4
c. BF_3 d. PF_3

42. Which of these is least likely to act as a Lewis base? *(2013)*

a. CO b. F^-
c. BF_3 d. PF_3

43. Which of the following is least likely to behave as Lewis base? *(2011 Prej)*

a. OH^- b. H_2O
c. NH_3 d. BF_3

44. Which one of the following molecular hydrides acts as a Lewis acid? *(2010 Prej)*

a. CH_4 b. NH_3
c. H_2O d. B_2H_6

45. The tendency of BF_3, BCl_3 and BBr_3 to behave as Lewis acid decreases in the sequence: *(2010 Prej)*

a. $BF_3 > BCl_3 > BBr_3$ b. $BCl_3 > BF_3 > BBr_3$
c. $BBr_3 > BCl_3 > BF_3$ d. $BBr_3 > BF_3 > BCl_3$

46. Which of the following molecules acts as a Lewis acid? *(2009)*

a. $(CH_3)_2O$ b. $(CH_3)_3P$
c. $(CH_3)_3N$ d. $(CH_3)_3B$

47. Which one of the following ionic species has the greatest proton affinity to form stable compound? *(2007)*

a. NH_2^- b. F^-
c. I^- d. HS^-

48. Which of the following statements is not true? *(2003)*

a. Among halide ions, iodide is the most powerful reducing agent
b. Fluorine is the only halogen that does not show a variable oxidation state
c. HOCl is a stronger acid than HOBr
d. HF is a stronger acid than HCl

49. In HS^-, I^-, $R\text{-}NH_2$, NH_3 order of proton accepting tendency will be: **[MR*]** *(2001)*

a. $I^- > NH_3 > R\text{-}NH_2 > HS^-$
b. $NH_3 > R\text{-}NH_2 > HS^- > I^-$
c. $RNH_2 > NH_3 > HS^- > I^-$
d. $HS^- > RNH_2 > NH_3 > I^-$

50. Conjugate acid of NH_2^-: *(2000)*

a. NH_4OH b. NH_4^+
c. NH^-_2 d. NH_3

51. The strongest conjugate base is: *(1999)*

a. NO_3^- b. Cl^-
c. SO_4^{2-} d. CH_3COO^-

52. The hydride ion H^- is stronger base than its hydroxide ion OH^-. Which of the following reaction will occur if sodium hydride (NaH) is dissolved in water? *(1997)*

a. $H^- + H_2O \rightarrow$ no reaction
b. $H^-(aq) + H_2O \rightarrow H_2O$
c. $H^-(aq) + H_2O(l) \rightarrow OH^- + H_2$
d. None of these

53. Which of the following is not a Lewis acid? **[MR*]** *(1996)*

a. SiF_4 b. C_2H_4
c. BF_3 d. $FeCl_3$

Ionization of Acids & Bases, pH Scale, Hydrolysis

54. For a weak acid HA, the percentage of dissociation in nearly 1% at equilibrium. If the concentration of acid is 0.1 mol L^{-1}, then the **correct** option for its K_a at the same temperature is: [MR*] *(2023-Manipur)*

a. 1×10^{-4} b. 1×10^{-6}
c. 1×10^{-5} d. 1×10^{-3}

55. 0.01 M acetic acid solution is 1% ionised, then pH of this acetic acid solution is: *(2022 Re)*

a. 1 b. 3
c. 2 d. 4

56. The pK_b of dimethylamine and pK_a of acetic acid are 3.27 and 4.77 respectively at T(K). The correct option for the pH of dimethyl ammonium acetate solution is: *(2021)*

a. 5.50 b. 7.75
c. 6.25 d. 8.50

57. Which among the following salt solutions is basic in nature? *(2020-Covid)*

a. Ammonium sulphate b. Ammonium nitrate
c. Sodium acetate d. Ammonium chloride

58. Following solutions were prepared by mixing different volumes of NaOH and HCl of different concentrations: [MR*] *(2018)*

A. $60\ mL\frac{M}{10}HCl + 40\ mL\frac{M}{10}NaOH$

B. $55\ mL\frac{M}{10}HCl + 45\ mL\frac{M}{10}NaOH$

C. $75\ mL\frac{M}{5}HCl + 25\ mL\frac{M}{5}NaOH$

D. $100\ mL\frac{M}{10}HCl + 100\ mL\frac{M}{10}NaOH$

pH of which one of them will be equal to 1?

a. B b. A
c. C d. D

59. The percentage of pyridine (C_5H_5N) that forms pyrimidine ion ($C_5H_5N^+H$) in a 0.10 M aqueous pyridine solution (K_b for $C_5H_5N = 1.7 \times 10^{-9}$) is: *(2016 - II)*

a. 0.77% b. 1.6%
c. 0.0060% d. 0.013%

60. What is the pH of the resulting solution when equal volumes of 0.1 M NaOH and 0.01 M HCl are mixed? *(2015 Re)*

a. 2.0 b. 7.0
c. 1.04 d. 12.65

61. Aqueous solution of which of the following compounds is the best conductor of electric current? *(2015 Re)*

a. Hydrochloric acid, HCl b. Ammonia, NH_3
c. Fructose, $C_6H_{12}O_6$ d. Acetic acid, $C_2H_4O_2$

62. Which of the following salts will give highest pH in water? [MR*] *(2014)*

a. NaCl b. Na_2CO_3
c. $CuSO_4$ d. KCl

63. Equimolar solutions of the following substances were prepared separately. Which one of these will record the highest pH value? *(2012 Pre)*

a. $BeCl_2$ b. $BaCl_2$
c. $AlCl_3$ d. LiCl

64. What is $[H^+]$ in mol L^{-1} of a solution that is 0.20 M in CH_3COONa and 0.10 M in CH_3COOH? K_a for $CH_3COOH = 1.8 \times 10^{-5}$. *(2010 Pre)*

a. 9.0×10^{-6} b. 3.5×10^{-4}
c. 1.1×10^{-5} d. 1.8×10^{-5}

65. The ionisation constant of ammonium hydroxide is 1.77×10^{-5} at 298 K. Hydrolysis constant of ammonium chloride is: *(2009)*

a. 6.50×10^{-12} b. 5.65×10^{-13}
c. 5.65×10^{-12} d. 5.65×10^{-10}

66. What is the (OH^-) in the final solution prepared by mixing 20.0 mL of 0.050 M HCl with 30.0 mL of 0.10 M $Ba(OH)_2$? *(2009)*

a. 0.40 M b. 0.0050 M
c. 0.12 M d. 0.10 M

67. The dissociation constants for acetic acid and HCN at 25°C are 1.5×10^{-5} and 4.5×10^{-10} respectively. The equilibrium constant for the equilibrium $CN^- + CH_3COOH \rightleftharpoons HCN + CH_3COO^-$ would be: *(2009)*

a. 3.0×10^{-5} b. 3.0×10^{-4}
c. 3.0×10^{4} d. 3.0×10^{5}

68. The dissociation equilibrium of a gas AB_2 can be represented as, $2AB_2(g) \rightleftharpoons 2AB(g) + B_2(g)$ The degree of dissociation is 'x' and is small compared to 1. The expression relating the degree of dissociation (x) with equilibrium constant K_P and total pressure P is: *(2008)*

a. $\left(\frac{K_P}{p}\right)$ b. $\left(\frac{2K_P}{p}\right)$
c. $\left(\frac{2K_P}{p}\right)^{1/3}$ d. $\left(\frac{2K_P}{p}\right)^{1/2}$

69. The values of K_{P_1} and K_{P_2} for the reactions

$X \rightleftharpoons Y + Z$..... (1) and

$A \rightleftharpoons AB$.....(2)

are in ratio of 9 : 1. If degree of dissociation of X and A be equal, then total pressure at equilibrium (1) and (2) are in the ratio: *(2008)*

a. 1 : 1 b. 3 : 1
c. 1 : 9 d. 36 : 1

70. Equal volumes of three acid solutions of pH 3, 4 and 5 are mixed in a vessel. What will be the H^+ ion concentration in the mixture? *(2008)*

a. 1.11×10^{-3} M b. 1.11×10^{-4} M
c. 3.7×10^{-4} M d. 3.7×10^{-3} M

71. Calculate the pOH of a solution at 25°C that contains 1×10^{-10} M of hydronium ions, i.e., H_3O^+: *(2007)*

a. 4.000 b. 9.0000
c. 1.000 d. 7.000

72. A weak acid, HA, has a K_a of 1.00×10^{-5}. If 0.100 mole of this acid dissolved in one litre of water, the percentage of acid dissociated at equilibrium is closest to: *(2007)*

a. 1.00% b. 99.9%
c. 0.100% d. 99.0%

73. The hydrogen ion concentration of a 10^{-8} M HCl aqueous solution at 298 K ($K_w = 10^{-14}$) is: *(2006)*

a. 1.0525×10^{-6} M b. 1.0525×10^{-7} M
c. 8.525×10^{-8} M d. 1.0525×10^{-8} M

74. Which has highest pH? *(2005)*

a. CH_3COOK b. Na_2CO_3
c. NH_4Cl d. $NaNO_3$

75. At 25°C, the dissociation constant of a base, BOH, is 1.0×10^{-12}. The concentration of hydroxyl ions in 0.01 M aqueous solution of the base would be: *(2005)*

a. 1.0×10^{-6} mol L^{-1} b. 1.0×10^{-5} mol L^{-1}
c. 1.0×10^{-8} mol L^{-1} d. 1.0×10^{-7} mol L^{-1}

76. In Haber process, 30 litres of dihydrogen and 30 litres of dinitrogen were taken for reaction which yielded only 50% of the expected product. What will be the composition of gaseous mixture under the above condition in the end? *(2003)*

a. 20 litres ammonia, 20 litres nitrogen, 20 litres hydrogen
b. 10 litres ammonia, 25 litres nitrogen, 15 litres hydrogen
c. 20 litres ammonia, 10 litres nitrogen, 30 litres hydrogen
d. 20 litres ammonia, 25 litres nitrogen, 15 litres hydrogen

77. Ionisation constant of CH_3COOH is 1.7×10^{-5} and concentration of H^+ ions is 3.4×10^{-4}. Then find out initial concentration of CH_3COOH molecules *(2001)*

a. 3.4×10^{-4} b. 3.4×10^{-3}
c. 6.8×10^{-4} d. 6.8×10^{-3}

78. Correct relation between dissociation constants of a di-basic acid: *(2000)*

a. $K_{a_1} = K_{a_2}$ b. $K_{a_1} > K_{a_2}$
c. $K_{a_1} < K_{a_2}$ d. $K_{a_1} = \frac{1}{K_{a_2}}$

79. Which statement is wrong about pH and H^+? *(2000)*

a. pH of neutral water is not zero
b. Adding solution of CH_3COOH and NaOH, pH will be seven
c. pH of dilute and hot H_2SO_4 is more than concentrated and cold H_2SO_4
d. Mixing solution of CH_3COOH and HCl, pH will be less than 7

80. The concentration of $[H^+]$ and concentration of $[OH^-]$ 0.1 M aqueous solution of 2% ionised weak monobasic aci [ionic product of water = 1×10^{-14}] $[MR^+]$ *(1*

a. 0.02×10^{-3} M and 5×10^{-11} M
b. 1×10^{-3} M and 3×10^{-11} M
c. 2×10^{-3} M and 5×10^{-12} M
d. 3×10^{-2} M and 4×10^{-13} M

81. Repeated use of which one of the following fertilisers wo increase the acidity of the soil? *(19*

a. Urea b. Superphosphate of lime
c. Ammonium sulphate d. Potassium nitrate

82. The ionic product of water at 25°C is 10^{-14}. Its ionic prod at 90°C will be: *(19*

a. 1×10^{-14} b. 1×10^{-16}
c. 1×10^{-20} d. 1×10^{-12}

83. If α is dissociation constant, then the total number of mo for the reaction $2HI \rightarrow H_2 + I_2$ will be: *(19*

a. 1 b. $1 - \alpha$
c. 2 d. $2 - \alpha$

84. The pH value of N/10 NaOH solution is: *(199*

a. 12 b. 13
c. 10 d. 11

85. The pH value of a 10 M solution of HC1 is: *(199*

a. Equal to 1 b. Equal to 2
c. Less than 0 d. Equal to 0

86. At 80°C, distilled water has $[H_3O^+]$ concentration equal t 1×10^{-6} mole L^{-1}. The value of K_w at this temperature will b *(199*

a. 1×10^{-12} b. 1×10^{-15}
c. 1×10^{-6} d. 1×10^{-9}

87. 0.1 M solution of which one of these substances will ac basic? *(1992*

a. Sodium borate b. Ammonium chloride
c. Calcium nitrate d. Sodium sulphate

88. Aqueous solution of acetic acid contains: *(1991*

a. CH_3COO^- and H^+
b. CH_3COO^-, H_3O^+ and CH_3COOH
c. CH_3COO^-, H_3O^+ and H^+
d. CH_3COOH, CH_3COO^- and H^+

89. The compound whose water solution has the highest pH is: *(1988)*

a. NaCl b. $NaHCO_3$
c. Na_2CO_3 d. NH_4Cl

Buffer Solutions

90. An acidic buffer is prepared by mixing: *(2023-Manipur)*

a. weak acid and it's salt with strong base
b. equal volume of equimolar solutions of weak acid and weak base.
c. strong acid and it's salt with strong base
d. strong acid and it's salt with weak base
(The pK_a of acid = pK_b of the base)

91. The pH of the solution containing 50 mL each of 0.10 M sodium acetate and 0.01 M acetic acid is *(2022)*
[Given pK_a of $CH_3COOH = 4.57$]
a. 2.57 b. 5.57
c. 3.57 d. 4.57

92. Which will make basic buffer? *(2019)*
a. 50 mL of 0.1 M NaOH + 25 mL of 0.1 M CH_3COOH
b. 100 mL of 0.1 M CH_3COOH + 100 mL of 0.1 M NaOH
c. 100 mL of 0.1 M HCl + 200 mL of 0.1 M NH_4OH
d. 100 mL of 0.1 M HCl + 100 mL of 0.1 M NaOH

93. Which one of the following pairs of solution is not an acidic buffer? [MR*] *(2015 Re)*
a. H_3PO_4 and Na_3PO_4
b. $HClO_4$ and $NaClO_4$
c. CH_3COOH and CH_3COONa
d. H_2CO_3 and Na_2CO_3

94. Buffer solutions have constant acidity and alkalinity because: *(2012 Pre)*
a. They have fixed value of pH
b. These give unionised acid or base on reaction with added acid or alkali
c. Acids and alkalies in these solutions are shielded from attack by other ions
d. They have large excess of H^+ or OH^- ions.

95. A buffer solution is prepared, in which the concentration of NH_3 is 0.30 M and the concentration of NH_4^+ is 0.20 M. If the equilibrium constant, K_b for NH_3 equals 1.8×10^{-5}, what is the pH of this solution?
(log 2.7 = 0.43) *(2011 Pre)*
a. 9.08 b. 9.43
c. 11.72 d. 8.73

96. In a buffer solution containing equal concentration of B^- and HB, the K_b for B^- is 10^{-10}. The pH of buffer solution is: *(2010 Pre)*
a. 4 b. 10
c. 7 d. 6

97. Which of the following pairs constitutes a buffer? *(2006)*
a. HNO_2 and $NaNO_2$ b. NaOH and NaCl
c. HNO_3 and NH_4NO_3 d. HCl and KCl

98. The rapid change of pH near the stoichiometric point of an acid-base titration is the basis of indicator detection. pH of the solution is related to ratio of the concentrations of the conjugate acid (HIn) and base (In^-) forms of the indicator by the expression: [MR*] *(2004)*
a. $\log\frac{[HIn]}{[In^-]} = pK_{In} - pH$ b. $\log\frac{[HIn]}{[In^-]} = pH - pK_{In}$
c. $\log\frac{[In^-]}{[HIn]} = pH - pK_{In}$ d. $\log\frac{[In^-]}{[HIn]} = pK_{In} - pH$

99. Solution of 0.1 N NH_4OH and 0.1 N NH_4Cl has pH 9.25. Then, find out pK_b of NH_4OH *(2002)*
a. 9.25 b. 4.75
c. 3.75 d. 8.25

100. A physician wishes to prepare a buffer solution at pH = 3.58, that efficiently resists changes in pH yet contains only small concentration of the buffering agents. Which one of the following weak acids together with its sodium salt would be best to use? [MR*] *(1997)*
a. 2,5-Dihydroxy benzoic acid ($pK_a = 2.97$)
b. Acetoacetic acid ($pK_a = 3.58$)
c. *m*-Chlorobenzoic acid ($pK_a = 3.98$)
d. *p*-Chlorocinnamic acid ($pK_a = 4.41$).

101. The pH value of blood does not appreciably change by a small addition of an acid or a base, because the blood: *(1995)*
a. Can be easily coagulated
b. Contains iron as a part of the molecule
c. Is a body fluid
d. Contains serum protein which acts as buffer

Solubility Equilibria of Sparingly Soluble Salts

102. Find out the solubility of $Ni(OH)_2$ in 0.1 M NaOH. Given that the ionic product of $Ni(OH)_2$ is 2×10^{-15}. *(2020)*
a. 2×10^{-8} M b. 1×10^{-13} M
c. 1×10^{8} M d. 2×10^{-13} M

103. HCl was passed through a solution of $CaCl_2$, $MgCl_2$ and NaCl. Which of the following compounds crystallizes? *(2020)*
a. Only NaCl b. Only $MgCl_2$
c. NaCl, $MgCl_2$ and $CaCl_2$ d. Both $MgCl_2$ and $CaCl_2$

104. The solubility product for a salt of the type AB is 4×10^{-8}. What is the molarity of its standard solution? *(2020-Covid)*
a. 16×10^{-16} mol/L b. 2×10^{-16} mol/L
c. 4×10^{-4} mol/L d. 2×10^{-4} mol/L

105. pH of a saturated solution of $Ca(OH_2)$ is 9. The solubility product (K_{sp}) of $Ca(OH)_2$ is: [MR*] *(2019)*
a. 0.5×10^{-15} b. 0.25×10^{-10}
c. 0.125×10^{-15} d. 0.5×10^{-10}

106. The solubility of $BaSO_4$ in water is 2.42×10^{-3} gL^{-1} at 298 K. The value of its solubility product (K_{sp}) will be *(2018)*
(Given molar mass of $BaSO_4 = 233$ g mol^{-1})
a. 1.08×10^{-10} mol^2 L^{-2} b. 1.08×10^{-12} mol^2 L^{-2}
c. 1.08×10^{-8} mol^2 L^{-2} d. 1.08×10^{-14} mol^2 L^{-2}

107. Concentration of the Ag^+ ions in a saturated solution of $Ag_2C_2O_4$ is 2.2×10^{-4} mol L^{-1}. Solubility product of $Ag_2C_2O_4$ is: *(2017-Delhi)*
a. 5.3×10^{-12} b. 2.42×10^{-8}
c. 2.66×10^{-12} d. 4.5×10^{-11}

108. The solubility of AgCl(s) with solubility product 1.6×10^{-10} in 0.1 M NaCl solution would be: *(2016 - II)*
a. 1.6×10^{-11} M b. Zero
c. 1.26×10^{-5} M d. 1.6×10^{-9} M

109. MY and NY_3, two nearly insoluble salts, have the same K_{sp} values of 6.2×10^{-13} at room temperature, which statements would be true in regard to MY and NY_3? [MR*] *(2016 - I)*

a. The addition of the salt of KY to solution of MY and NY_3 will have no effect on their solubilities

b. The molar solubilities of MY and NY_3 in water are identical

c. The molar solubility of MY in water is less than that of NY_3

d. The salts MY and NY_3 are more soluble in 0.5 M KY than in pure water

110. The K_{sp} of Ag_2CrO_4, AgCl, AgBr and AgI are respectively, 1.1×10^{-12}, 1.8×10^{-10}, 5.0×10^{-13}, 8.3×10^{-17}. Which one of the following salts will precipitate last if $AgNO_3$ solution is added to the solution containing equal moles of NaCl, NaBr, NaI and Na_2CrO_4? *(2015)*

a. AgCl b. AgBr

c. Ag_2CrO_4 d. AgI

111. Using the Gibb's energy change, $\Delta G^\circ = +63.3$ kJ, for the following reaction,

$$Ag_2CO_3(s) \rightleftharpoons 2Ag^+(aq) + CO_3^{2-}(aq)$$

the K_{sp} of $Ag_2CO_3(s)$ in water at 25°C is ($R = 8.314$ J K^{-1} mol^{-1}) *(2014)*

a. 3.2×10^{-26} b. 8.0×10^{-12}

c. 2.9×10^{-3} d. 7.9×10^{-2}

112. Identify the correct order of solubility in aqueous medium: *(2013)*

a. $Na_2S > CuS > ZnS$

b. $Na_2S > ZnS > CuS$

c. $CuS > ZnS > Na_2S$

d. $ZnS > Na_2S > CuS$

113. pH of a saturated solution of $Ba(OH)_2$ is 12. The value of solubility product (K_{sp}) of $Ba(OH)_2$ is: *(2012 Pre)*

a. 5.0×10^{-6} b. 3.3×10^{-7}

c. 5.0×10^{-7} d. 4.0×10^{-6}

114. In qualitative analysis, the metals of group I can be separated from other ions by precipitating them as chloride salts. A solution initially contains Ag^+ and Pb^{2+} at a concentration of 0.10 M. Aqueous HCl is added to this solution until the Cl^- concentration is 0.10 M, What will the concentration of Ag^+ and Pb^{2+} be at equilibrium?

(K_{sp} for AgCl = 1.8×10^{-10}, K_{sp} for $PbCl_2 = 1.7 \times 10^{-5}$) *(2011 Mains)*

a. $[Ag^+] = 1.8 \times 10^{-9}$ M, $[Pb^{2+}] = 1.7 \times 10^{-3}$ M

b. $[Ag^+] = 1.8 \times 10^{-11}$ M, $[Pb^{2+}] = 1.7 \times 10^{-4}$ M

c. $[Ag^+] = 1.8 \times 10^{-7}$ M, $[Pb^{2+}] = 1.7 \times 10^{-6}$ M

d. $[Ag^+] = 1.8 \times 10^{-11}$ M, $[Pb^{2+}] = 8.5 \times 10^{-5}$ M

115. If pH of a saturated solution of $Ba(OH)_2$ is 12, the value of its K_{sp} is: *(2010 Pre)*

a. 5.00×10^{-7} M^3 b. 4.00×10^{-6} M^3

c. 4.00×10^{-7} M^3 d. 5.00×10^{-6}

116. H_2S gas when passed through a solution of cations containing HCl, precipitates the cations of second group in qualitative analysis but not those belonging to the fourth group. It is because: *(2009)*

a. Presence of HCl decreases the sulphide ion concentration

b. Presence of HCl increases the sulphide ion concentration

c. Solubility product of group II sulphides is more than that of group IV sulphides

d. Sulphides of group IV cations are unstable in HCl

117. The solubility product of a sparingly soluble salt AX_2 is 3.2×10^{-11}. Its solubility (in moles L^{-1}) is: *(2004)*

a. 3.1×10^{-4} b. 2×10^{-4}

c. 4×10^{-4} d. 5.6×10^{-6}

118. The solubility product of AgI at 25°C is 1.0×10^{-16} $mol^2 L^{-2}$. The solubility of AgI in 10^{-4} N solution of KI at 25° C is approximately (in mol L^{-1}): *(2002)*

a. 1.0×10^{-16} b. 1.0×10^{-12}

c. 1.0×10^{-10} d. 1.0×10^{-8}

119. Solubility, of MX_2 – type electrolytes is 0.5×10^{-4} Mole/lit then find out K_{sp} of electrolytes. *(2002)*

a. 5×10^{-12} b. 25×10^{-10}

c. 1×10^{-13} d. 5×10^{-13}

120. Solubility of a M_2S salt is 3.5×10^{-6}, then find out solubility product. *(2001)*

a. 1.7×10^{-6} b. 1.7×10^{-16}

c. 1.7×10^{-18} d. 1.7×10^{-12}

121. The solubility of a saturated solution of calcium fluoride is 2×10^{-4} mol L^{-1}. Its solubility product is: *(1996)*

a. 12×10^{-2} b. 14×10^{-4}

c. 22×10^{-11} d. 32×10^{-12}

122. The solubility product of CuS, Ag_2S and HgS are 10^{-31}, 10^{-4} and 10^{-54} respectively. The solubilities of these sulphides are in the order: [MR*] *(1997)*

a. $HgS > Ag_2S > CuS$ b. $CuS > Ag_2S > HgS$

c. $Ag_2S > Cus > HgS$ d. $AgS > HgS > CuS$

123. The solubility of AgCl will be minimum in: *(1995)*

a. 0.01 M $CaCl_2$ b. Pure water

c. 0.001 M $AgNO_3$ d. 0.01 M NaCl

124. Which one of the following is most soluble? *(1994)*

a. Bi_2S_3 ($K_{sp} = 1 \times 10^{-70}$) b. Ag_2S ($K_{sp} = 6 \times 10^{-51}$)

c. CuS ($K_{sp} = 8 \times 10^{-37}$) d. MnS ($K_{sp} = 7 \times 10^{-16}$)

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Answer Key

1. (c)	**2.** (b)	**3.** (c)	**4.** (b)	**5.** (b)	**6.** (d)	**7.** (d)	**8.** (d)	**9.** (b)	**10.** (a)
11. (c)	**12.** (d)	**13.** (d)	**14.** (c)	**15.** (d)	**16.** (a)	**17.** (d)	**18.** (c)	**19.** (a)	**20.** (a)
21. (d)	**22.** (d)	**23.** (a)	**24.** (c)	**25.** (b)	**26.** (c)	**27.** (a)	**28.** (a)	**29.** (c)	**30.** (c)
31. (a)	**32.** (d)	**33.** (b)	**34.** (c)	**35.** (b)	**36.** (b)	**37.** (c)	**38.** (d)	**39.** (d)	**40.** (c)
41. (d)	**42.** (c)	**43.** (d)	**44.** (d)	**45.** (c)	**46.** (d)	**47.** (a)	**48.** (d)	**49.** (c)	**50.** (d)
51. (d)	**52.** (c)	**53.** (b)	**54.** (c)	**55.** (d)	**56.** (b)	**57.** (c)	**58.** (c)	**59.** (d)	**60.** (d)
61. (a)	**62.** (b)	**63.** (b)	**64.** (a)	**65.** (d)	**66.** (d)	**67.** (c)	**68.** (c)	**69.** (d)	**70.** (c)
71. (a)	**72.** (a)	**73.** (b)	**74.** (b)	**75.** (d)	**76.** (b)	**77.** (d)	**78.** (b)	**79.** (b)	**80.** (c)
81. (c)	**82.** (d)	**83.** (c)	**84.** (b)	**85.** (c)	**86.** (a)	**87.** (a)	**88.** (b)	**89.** (c)	**90.** (a)
91. (b)	**92.** (c)	**93.** (b)	**94.** (b)	**95.** (b)	**96.** (a)	**97.** (a)	**98.** (c)	**99.** (b)	**100.** (b)
101. (d)	**102.** (d)	**103.** (a)	**104.** (d)	**105.** (a)	**106.** (a)	**107.** (a)	**108.** (d)	**109.** (c)	**110.** (c)
111. (b)	**112.** (b)	**113.** (c)	**114.** (a)	**115.** (a)	**116.** (a)	**117.** (b)	**118.** (b)	**119.** (d)	**120.** (b)
121. (d)	**122.** (b)	**123.** (a)	**124.** (d)						

Explanations

1. (c) The given reaction

$CO_2(g) + C(s) \rightleftharpoons 2CO(g)$

Given, $K_p = 3.0$

$K_P = K_c (RT)^{\Delta n_g}$

$|\Delta n_g = 2 - 1| = 1$

$\therefore 3 = K_c (0.083 \times 1000)$

$$\Rightarrow K_c = \frac{3}{0.083 \times 1000} = 3.6 \times 10^{-2}$$

2. (b) The given reaction is:

$3O_2(g) \rightleftharpoons 2O_3(g)$

Equilibrium constant (K_C) is the ratio of products concentration to reactant concentrations.

$$K_c = \frac{[O_3]^2}{[O_2]^3}$$

Substitute the given values in above expression as:

$$3\times10^{-59} = \frac{[O_3]^2}{(4\times10^{-2})^3}$$

$[O_3]^2 = 3 \times 10^{-59} \times 64 \times 10^{-6}$

$[O_3]^2 = 19.2 \times 10^{-64}$

$[O_3] = 4.38 \times 10^{-32}$ M

3. (c) Whenever a reaction is reversed, equilibrium constant becomes reciprocal of its original value.

$2NH_3 \rightleftharpoons N_2 + 3H_2 \quad \frac{1}{K_1}$ ...(i)

$N_2 + O_2 \rightleftharpoons 2NO \quad K_2$ ...(ii)

Whenever a reaction is multiplied by any number, then that coefficient becomes power of the equilibrium constant.

$3H_2 + \frac{3}{2}O_2 \rightleftharpoons 3H_2O \quad K_3^3$ ...(iii)

On adding reactions, final equilibrium constant will be multiplied with each other.

$2NH_3 + \frac{5}{2}O_2 \rightleftharpoons 2NO + 3H_2O$

$$K = \frac{K_2K_3^3}{K_1}$$

4. (b) Whenever a reaction is multiplied by any number, then that number becomes power of the new equilibrium constant.

$\frac{1}{2}N_2 + \frac{1}{2}O_2 \rightleftharpoons NO \quad K' = K^{1/2}$

5. (b) Equilibrium constant expression in terms of products and reactants is

$$K = \frac{[\text{Products}]}{[\text{Reactants}]}$$

If the value of K is very high, it indicates that ratio of products to reactant concentration will also be very high. As a result, the reaction mixture mostly consists of products.

6. (d) Equilibrium Constant is defined as the ratio of concentrations of products to reactants raised to their stoichiometric coefficients.

$A_2(g) + B_2(g) \rightleftharpoons 2AB(g)$

$$K_C = \frac{[AB]^2}{[A_2][B_2]} = \frac{(2.8\times10^{-3})^2}{[3\times10^{-3}][4.2\times10^{-3}]} = 0.62$$

7. (d) First a reaction is reversed, then,

$$K' = \frac{1}{K}$$

Now, a reaction is multiplied by $\frac{1}{2}$, then,

$$K' = \frac{1}{K^{1/2}}$$

$$= \frac{1}{\sqrt{278}} \approx 6\times10^{-2}$$

8. (d) $N_2(g)+O_2(g) \rightleftharpoons 2NO(g)$; K_1

$2NO+O_2 \rightleftharpoons 2NO_2$; K_2

For $K_1 \times K_2 = N_2(g)+2O_2 \rightleftharpoons 2NO_2(g)$

For $NO_2(g) \rightleftharpoons \frac{1}{2}N_2(g)+O_2(g)$

$$K^1 = \left[\frac{1}{K_1K_2}\right]^{1/2}$$

9. (b) $2A+B \rightleftharpoons 3C+D$

$$K_c = \frac{[D][C]^3}{[A]^2[B]} = \frac{[0.25][0.75]^3}{[0.5]^2[0.75]}$$

	2A +	B ⇌	3C +	D
Initial	1	1	0	0
At Equilibrium	1 – 0.5	0.75	0.75	0.25

$K_c = [(0.75)^3(0.25)] \div [(0.5)^2(0.75)]$

10. (a) Relation between K_p and K_c is: $K_p = K_c(RT)^{\Delta n}$

For $2C(s)+O_2(g) \rightleftharpoons 2CO(g)$

Difference in number of moles of gaseous reactant & products is not zero. So,

$K_p \neq K_c$

11. (c) $HI(g) \rightleftharpoons \frac{1}{2}H_2(g)+\frac{1}{2}I_2(g)$ $\quad K=8.0$

First a reaction is reversed, then it is multiplied by 2.

$$K' = \frac{1}{K^2} = \frac{1}{64}$$

12. (d) The required equation for oxidation of NH_3 by oxygen to give NO is:

$$4NH_3+5O_2 \xrightarrow[800°C]{Pt(gauze)} 4NO+6H_2O$$

$$K = \frac{[NO]^4[H_2O]^6}{[NH_3]^4[O_2]^5}$$

For the equation (i), $K_1 = \frac{[NH_3]^2}{[N_2][H_2]^3}$

For the equation (ii), $K_2 = \frac{[NO]^2}{[N_2][O_2]}$

For the equation (iii), $K_3 = \frac{[H_2O]}{[H_2][O_2]^{1/2}}$

For getting K:

$$K_1^2 = \frac{[NH_3]^4}{[N_2]^2[H_2]^6}, K_2^2 = \frac{[NO]^4}{[N_2]^2[O_2]^2}$$

$$K_3^6 = \frac{[H_2O]^6}{[H_2]^6[O_2]^{6/2}}$$

$K = \frac{K_2^2 \times K_3^6}{K_1^2}$ Substituting the values

$$K = \frac{[NO]^4[H_2O]^6}{[NH_3]^4[O_2]^5}$$

In terms of K_1, K_2 and K_3 is:

$$K = \frac{K_2K_3^3}{K_1}$$

13. (d) $NO(g)+\frac{1}{2}O_2 \overset{K_1}{\rightleftharpoons} NO_2(g)$

$2NO_2(g) \overset{K_2}{\rightleftharpoons} 2NO(g)+O_2(g)$

$$K_1 = \frac{[NO_2]}{[NO][O_2]^{1/2}} \Rightarrow K_2 = \frac{[NO]^2[O_2]}{[NO_2]^2}$$

By comparing, $K_2 = \frac{1}{K_1^2}$

14. (c) $N_2+3H_2 \rightleftharpoons 2NH_3$

$$K_C = \frac{[NH_3]^2}{[N_2][H_2]^3}; \Delta n = 2-4 = -2$$

$Q > K_C$

15. (d) $N_2+3H_2 \rightleftharpoons 2NH_3$

$$K_1 = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

$N_2+O_2 \rightleftharpoons 2NO$

$$K_2 = \frac{[NO]^2}{[N_2][O_2]}$$

$H_2+\frac{1}{2}O_2 \rightleftharpoons H_2O$

$$K_3 = \frac{[H_2O]}{[H_2][O_2]^{1/2}}$$

For the reaction

$2NH_3+\frac{5}{2}O_2 \rightleftharpoons 2NO+3H_2O$

$$K = \frac{[NO]^2[H_2O]^3}{[NH_3]^2[O_2]^{5/2}}$$

$$= \frac{[NO_2]^2}{[N_2][O_2]} \times \frac{[H_2O]^3}{[H]^3[O_2]^{3/2}} \times \frac{[N_2][H_2]^3}{[NH_3]^2}$$

$$= \frac{K_2 \times K_3^3}{K_1}$$

16. (a) $K_P = p_{CO_2}$

Solids do not exert pressure, so their partial pressure is ta as unity.

17. (d) $XeF_6(g)+H_2O(g)\rightleftharpoons XeOF_4(g)+2HF(g)$

$$K_1=\frac{[XeOF_4][HF]^2}{[XeF_6][H_2O]} \quad ...(i)$$

$XeO_4(g)+XeF_6(g)\rightleftharpoons XeOF_4(g)+XeO_3F_2(g)$

$$K_2=\frac{[XeOF_4][XeO_3F_2]}{[XeO_4][XeF_6]} \quad ...(ii)$$

For reaction:

$XeO_4(g)+2HF(g)\rightleftharpoons XeO_3F_2(g)+H_2O(g)'$

$$K=\frac{[XeO_3F_2][H_2O]}{[XeO_4][HF]^2}$$

∴ From eqn (i) and (ii):

$$K=\frac{K_2}{K_1}$$

18. (c) The equilibrium constant for the reverse reaction will be 1/K.

19. (a) Vapour pressure is directly related to temperature. Greater is the temperature, greater will be the vapour pressure. So to keep it constant, temperature should be constant.

20. (a) Reaction (ii) is the reversible reaction of (i) and is half of the reaction (i). Thus, rate constant can be given as:

$$K_2=\sqrt{\frac{1}{K_1}} \text{ or } K_1=\left[\frac{1}{K_2}\right]^2$$

21. (d) $K_{eq.}=\frac{[C][D]}{[A][B]}$

$K_{eq}=(10\times 6)/(2\times 3)=10$

$\Delta G^0=-2.303\ RT\log K_{eq.}=-2.303(2)(300)(\log 10)$

$=-1381.8$ cal $(\because R=2$ cal/mol k)

22. (d) Given: $K=2\times 10^{13}$

$\Delta G=\Delta G°+RT\ \ln Q$

At equilibrium, $\Delta G=0$, $Q=K_{eq}$

So $\Delta_r G°=-RT\ \ln K_{eq}$

Substitute the values in above equation as:

$\Delta_r G°=-8.314\ J\ mol^{-1}\ K^{-1}\times 300\ K\times \ln(2\times 10^{13})$

23. (a) According to Le-Chatelier's principle, on changing the conditions of temperature, volume, pressure or number moles at equilibrium, the reaction will shift in forward or backward direction to neutralize the change. The reaction having negative value of ΔH is an exothermic reaction while positive value of ΔH is an endothermic reaction.

$A_2(g)+B_2(g)\rightleftharpoons X_2(g);\Delta H=-X\ kJ$

On increasing pressure, equilibrium shifts in a direction where pressure decreases i.e. forward direction.

On decreasing temperature, equilibrium shifts in forward direction as it is exothermic direction.

So, high pressure and low temperature favours maximum formation of product.

24. (c) The value of equilibrium constant is not changed in the presence of a catalyst in the reaction at equilibrium. The catalyst only increases the rate of reaction, it does not affect the equilibrium constant.

Also, the value of equilibrium constant depends only on temperature. Its value will change with a change in temperature.

25. (b) Max. pressure of CO_2 = Pressure of CO_2 at equilibrium

For reaction,

$SrCO_3(s)\rightleftharpoons SrO(s)+CO_2$

1.6 atm = maximum pressure of CO_2

Volume of container at this stage, (By using ideal gas equation)

$$V=\frac{nRT}{P} \quad ...(i)$$

Since container is sealed and reaction was not earlier at equilibrium, then

∴ n = constant

$$n=\frac{PV}{RT}=\frac{0.4\times 20}{RT} \quad ...(ii)$$

Put equation (ii) in equation (i):

$$V=\left[\frac{0.4\times 20}{RT}\right]\frac{RT}{1.6}=5\ L$$

26. (c) If large amount of $KHSO_4$ would be added, then concentration of NO_2^+ will decrease, rate of nitration will also decrease.

The reaction can be written as:

$HNO_3+H_2SO_4\longrightarrow NO_2^++HSO_4^-+H_3O^+$

On adding the large amount of $KHSO_4$, concentration of HSO_4^- will increase, then the reaction will shift in backward direction.

27. (a) The relation between ΔG and ΔG° at any temperature is given by:

$\because \Delta G=\Delta G°+2.303\ RT\log Q$

At equilibrium:

$\Delta G=0$

$Q=K_{eq}$

So, $\Delta G°=(-)\ 2.303\ RT\log K_{eq}$

28. (a) For exothermic reaction, ΔH° should be negative.

For the given conditions, the formula will be:

$$\log\frac{K_p'}{K_p}=\frac{\Delta H°}{2.303R}\left[\frac{1}{T_1}-\frac{1}{T_2}\right]$$

Here, K_p is equilibrium constant at temp. T_1

Here, K'_p is equilibrium constant at temp. T_2

ΔH° is standard enthalpy change

R is gas constant

Let assume that $T_2>T_1$.

Under this condition, $K_p>K'_p$ for exothermic reaction.

29. (c) On increasing pressure, equilibrium shifts in forward direction, where number of moles decreases, it is an example of exothermic reaction therefore, decreasing temperature favours the forward direction.

30. (c) HCl and SO_2 are reducing agents so, they can reduce MnO_4^-.

CO_2 is neither oxidising nor reducing agent, it will provide only acidic medium and shift the direction in forward reaction towards completion.

31. **(a)** $X_2(g) + 4Y_2(g) \rightleftharpoons 2XY_4(g)$

Δn_g = –ve and ΔH = –ve

The reaction is favoured in forward direction at low temperature and high pressure. This is in accordance with Le-Chatelier's principle.

32. **(d)** $Fe(OH)_3(s) \rightleftharpoons Fe^{3+}(aq) + 3OH^-(aq)$

$K = [Fe^{3+}][OH^-]^3$ (activity of solid is taken unity)

Concentration of OH^- ion in the reaction is decreased by 1/4 times, then equilibrium concentration of Fe^{3+} will be increased by 64 times, in order to keep the value of K constant.

33. **(b)** While writing the expression of K_c, species present in pure solids or liquid are not included. Now, for a given reaction, expression of K_p is:

$$K_p = \frac{P_{CO_2}}{P_{CH_4} \cdot P_{O_2}^2}$$

34. **(c)** $BaO_2(s) \rightleftharpoons BaO(s) + O_2(g)$

Pressure of O_2 does not depend on concentration terms of other reactants (as both are in solid state), since this is an endothermic reaction. If the temperature is raised, dissociation of BaO_2 would occur more O_2 is produced at equilibrium, pressure of O_2 increases.

35. **(b)** For a reaction, $A + B \rightleftharpoons C + D$

$$K_{eq} = \frac{[C][D]}{[A][B]}$$

Increase in concentration of reactants will proceed the equilibrium in the forward direction giving more products, so that the equilibrium constant value remains constant and becomes independent of concentration.

36. **(b)** Since a catalyst affects equally on both forward and backward reactions, therefore it does not affect equilibrium constant of reaction. It only provides an alternate pathway.

37. **(c)** If more *trans*-2-pentene is added, then its concentration in right hand side will increase. But in order to maintain the constant *K*, concentration of *cis*-2-pentene will also increase. Therefore, more *cis*-2-pentene will be formed.

38. **(d)** When solid and liquid are in equilibrium. the increase in temperature results in increase in volume of liquid or decrease in the amount of solid.

Solid $\rightleftharpoons$ Liquid

With increase in temperature, equilibrium shifts in forward direction which means amount of solid will decrease.

39. **(d)** According to Le Chatelier's principle, if an equilibrium is subjected to a change in concentration, pressure or temperature, etc. equilibrium shift in such a way so as to undo the effect of a change imposed.

40. **(c)** Conjugate base is formed by the removal of H^+ ion while conjugate acid is formed by the addition of H^+ ion to the given species. Let us take an example of H_2O:

$$\underset{\text{Conjugate base}}{OH^{\ominus}} \xleftarrow{-H^+} H_2O \xrightarrow{+H^+} \underset{\text{Conjugate acid}}{H_3O^+}$$

So, for the reaction:

$$\underset{\text{Acid}}{HF} + \underset{\text{Base}}{H_2O} \rightleftharpoons \underset{\text{Conjugate base}}{F^{\ominus}} + \underset{\text{Conjugate acid}}{H_3O^+}$$

41. **(d)** Species which can donate a pair of elections are known as Lewis bases. Among the 4 options, PF_3 will behave as a Lewis base due to presence of lone pair of electrons in p-orbitals.

42. **(c)** Lewis acid species are those which are electron deficient and does require electron to complete their octet. BF_3 is an electron deficient species and is a Lewis acid.

43. **(d)** BF_3 is an electron deficient species and acts as Lewis acid. It requires electron to complete its octet.

44. **(d)** B_2H_6 is an electron deficient compound with 6 electrons in outer octet and thus, acts as a Lewis acid.

45. **(c)** In BF_3, there is considerable amount of pπ-dπ back bonding, as a result of which it appears less electron deficient. Whereas, in BCl_3 and BBr_3, the size of p and d-orbitals are not same due to which back bonding do not occurs.

Hence, they have more tendency to accept any electron.

The order is:

$BBr_3 > BCl_3 > BF_3$

46. **(d)** $(CH_3)_3B$ is an electron deficient compound and it behave as a Lewis acid. It has 6 electrons in its octet.

47. **(a)** Proton affinity decreases when we move across the period from left to right due to increase in charge, within a group, the proton affinity decreases from top to bottom.

Nitrogen family > Oxygen family > Halogens

48. **(d)** Due to strong hydrogen fluorine bond, proton is not given off easily and hence, HF is the weakest acid.

49. **(c)** Proton accepting tendency is known as the strength of basicity.

In R—$\ddot{N}H_2$, N has lone pair of electron which intensify due to electron releasing R group and increase the tendency to donate lone pair of electron to H^+.

Secondly, as the size of the ion increases, there is less attraction for H^+ to form weaker bond with H-atom and is less basic.

50. **(d)** $NH_2^- + H^+ \rightarrow NH_3$ (conjugate acid)

Substance + H^+ → Conjugate acid

Substance – H^+ → Conjugate base

51. **(d)** Weaker the acid, stronger will be its conjugate base or vice-versa. Among the giver options, CH_3COO^- is the strongest conjugate base as its conjugate acid (CH_3COOH) is the weakest one among the given options.

52. **(c)** $NaH + H_2O \rightarrow NaOH + H_2$

or $H^-(aq) + H_2O(l) \rightarrow OH^- + H_2\uparrow$

Hydride ions will abstract proton form NaOH and hydrogen gas will evolve as a result of it.

53. **(b)** In BF_3 and $FeCl_3$ molecules, the central atoms have incomplete octet and in SiF_4, the central atom has empty *d*-orbitals. Hence, according to Lewis concept, these are Lewis acids.

54. **(c)** Dissociation constant can be calculated as:

$K_a = C\alpha^2$

$K_a = (0.1) \times (0.01)^2$

$K_a = 1 \times 10^{-5}$

55. (d)

	$CH_3COOH \rightleftharpoons$	$CH_3COO^- +$	H^+
$t=0$	C	C	O
$t=t_{eq}$	$C-C\alpha$	$C\alpha$	$C\alpha$

Given, $\alpha = 1\% = \frac{1}{100}$

$[H^+] = C.\alpha$

$= 0.01 \times \frac{1}{100} = 0.0001 = 10^{-4} M$

$pH = -\log_{10}[H^+]$

$= -\log [10^{-4}] = 4$

56. (b) Dimethylammonium acetate is a salt of weak acid and weak base.

Given,

pK_a of acetic acid = 4.77

pK_b of dimethylamine = 3.27

For a salt of weak acid and weak base, the formula to calculate pH is:

$$pH = 7 + \frac{1}{2}(pK_a - pK_b)$$

Substitute the given values in above equation as:

$$= 7 + \frac{1}{2}(4.77 - 3.27) = 7.75$$

57. (c) Acetic acid, CH_3COOH, will react with sodium hydroxide, NaOH, to produce sodium acetate, CH_3COONa, and water.

Sodium acetate is a salt of strong base and weak acid, therefore, its salt solution is basic in nature.

$CH_3COONa \leftrightharpoons CH_3COOH$ (WA) + NaOH (SB)

58. (c) A. M_{eq} of HCl = Molarity × Volume = $60 \times \frac{1}{10} = 6$

M_{eq} of NaOH = Molarity × Volume = $40 \times \frac{1}{10} = 4$

M_{eq} of HCl = Molarity × Volume = 6 – 4 = 2

M_{eq} of $[H^+]$ in resulting mixture = $\frac{\text{Moles}}{\text{Volume}} = \frac{2}{100} = \frac{1}{50}$

$$pH = -\log [H^+] = -\log \left[\frac{1}{50}\right] \approx 1.7$$

B. M_{eq} of HCl = M × V = $55 \times \frac{1}{10} = 5.5$

M_{eq} of NaOH = M × V = $45 \times \frac{1}{10} = 4.5$

M_{eq} of HCl in resulting solution = 55 –4.5 = 1.0

Molarity of $[H^+]$ in resulting mixture = $\frac{\text{Moles}}{\text{Volume}} = \frac{1}{100}$

$$pH = -\log [H^+] = -\log \left[\frac{1}{100}\right] = 2$$

C. M_{eq} of HCl = $75 \times \frac{1}{5} \times 1 = 15$

M_{eq} of NaOH = $25 \times \frac{1}{5} \times 1 = 5$

M_{eq} of HCl in resulting solution = 15 – 5 =10

Molarity of $[H^+]$ in resulting mixture:

$\frac{\text{Moles}}{\text{Volume}} = \frac{10}{100} = \frac{1}{10}$

$$pH = -\log[H^+] = -\log\left[\frac{1}{10}\right] = 1.0$$

D. M_{eq} of HCl = M × V = $100 \times \frac{1}{10} = 10$

M_{eq} of NaOH = M × V = $100 \times \frac{1}{10} = 10$

In this composition, neutral solution will form.

59. (d) Pyrimidine is a very weak base so, $K_b = c\alpha^2$

$$\alpha = \sqrt{\frac{K_b}{c}}$$

Substitute the values in above equation.

$$\alpha = \sqrt{\frac{1.7 \times 10^{-9}}{0.9}} = 1.3 \times 10^{-4}$$

$\% \alpha = 0.013\%$

60. (d) ∵ 1 mole of NaOH is completely neutralised by 1 mole of HCl.

$NaOH + HCl \longrightarrow NaCl + H_2O$

So, 0.01 mole is neutralised by 0.01 mole of HCl.

Left NaOH = 0.09 mole (1 – 0.01)

$$[OH^-] = \frac{\text{Moles}}{\text{Volume}} = \frac{0.09}{2} = 0.045\ M$$

$pOH = -\log [OH^-] = 1.35$

pH = 14 – pOH = 14 – 1.35 = 12.65

61. (a) HCl is a strong acid and dissociated completely into ions in aq solution. As a result, it will be the best conductor of electric current.

62. (b) Na_2CO_3 being salt of a strong base and weak acid will exhibit highest pH.

Both NaCl and KCl are neutral salts as these are formed from strong acid and strong base.

$NaOH + HCl \rightarrow NaCl + H_2O$

$KOH + HCl \rightarrow KCl + H_2O$

$CuSO_4$ is acidic in nature as it is formed from strong acid weak base.

$Cu(OH)_2 + H_2SO_4 \rightarrow CuSO_4 + 2H_2O$

$NaCl \rightarrow$ Neutral, pH = 7

$CuSO_4 \rightarrow$ Acidic, pH < 7

$KCl \rightarrow$ Neutral, pH = 7

63. (b) $BaCl_2$ is a salt of strong acid HCl and strong base $Ba(OH)_2$. So, it's aqueous solution is neutral with pH 7. All other salts gives acidic solution due to cationic hydrolysis, so their pH is less than 7. Thus, pH value is highest for solution of $BaCl_2$.

$Ba(OH)_2 + 2HCl \rightarrow BaCl_2 + 2H_2O$

64. (a)

	$CH_3COOH \rightleftharpoons$	$CH_3COO^- +$	H^+
	$C-x$	x	x

	$CH_3COONa \rightleftharpoons$	$CH_3COO^- +$	Na^+
	0.2	0.2	

K_a for $CH_3COOH^- \rightleftharpoons \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$

Now, $[CH_3COOH] = C - x \approx C = 0.1\ M$

$[CH_3COO^-] = 0.2 + x$

$[H^+] = \frac{K_a \times 0.1}{0.2+x}$

$[H^+] = \frac{1.8\times10^{-5}\times0.1}{0.2}$

$[H^+] = 9\times10^{-6}$

65. (d) The relation between K_w, K_h and K_b is:

$K_h = \frac{K_W}{K_b}$

The value of K_w at 298 K is 1×10^{-14}.

Substitute the given values in above equation as:

$K_b = \frac{1\times10^{-14}}{1.77\times10^{-5}} = 5.65\times10^{-10}$

66. (d) ∵ Each $Ba(OH)_2$ gives 2 OH^-.

Mol of HCl = M × V = 0·050 × 0.02 = 1×10^{-3}

Mole of $Ba(OH)_2$ = M × V = 0.10 × 0.03 = 3×10^{-3}

Moles of OH^- = $2 \times 3 \times 10^{-3} = 6 \times 10^{-3}$

Remaining moles of OH^- = $(6 - 1) \times 10^{-3} = 5 \times 10^{-3}$

$[OH^-] = \frac{\text{Moles}}{\text{Total Volume}} = \frac{5\times10^{-3}}{0.05} = 0.1\ M$

67. (c) K_a for $HCN = \frac{[CN^-][H^+]}{[HCN]}$

K_a for $CH_3COOH = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$

or, $CN^- + CH_3COOH \rightleftharpoons HCN + CH_3COO^-$

$K_{eq} = \frac{[HCN][CH_3COO^-]}{[CN^-][CH_3COOH]}$

$= \frac{1.5\times10^{-5}}{4.5\times10^{-10}} \Rightarrow 0.3 \times 10^5$

$= 3\times10^4$

68. (c) According to chemical equation:

	$2AB_2(g) \rightleftharpoons$	$2AB(g) + B_2(g)$	
Initial	1	0	0
At equilibrium	1 − x	x	$\frac{x}{2}$

Total number of moles at equilibrium: $1 - x + \frac{x}{2} = 1 + \frac{x}{2}$

$$K_p = \frac{\left(\frac{x}{1+\frac{x}{2}}\times p\right)\left(\frac{\frac{x}{2}}{1+\frac{x}{2}}\times p\right)}{\left(\frac{1-x}{1+\frac{x}{2}}\times p\right)} \Rightarrow K_p = \frac{x^3 p}{2}$$

So, x = degree of dissociation

$x^3 = \frac{2K_p}{p}$

$x = \left(\frac{2K_p}{p}\right)^{1/3}$

69. (d) As per the equation:

$X \rightleftharpoons Y + Z;\ A \rightleftharpoons 2B$

Initial	1	0	0	1	0
	1 − x	x	x	1 − x	2

$K_{P_1} = \frac{\left(\frac{x}{1+x}\times p^2\right)}{\frac{1-x}{1+x}\times p}$

$K_{P_2} = \frac{\left(\frac{2x}{1+x}\times p'\right)^2}{\frac{1-x}{1+x}\times p'}$

$\frac{K_{P_1}}{K_{P_2}} = \frac{p}{4p'}$ or $\frac{9}{1} = \frac{p}{4p'}$

$36p' = p$

$\frac{p}{p'} = 36:1$

70. (c) For solutions $pH = -\log[H^+]$

$3 = -\log[H^+]$

$[H]^+ = 10^{-3}$

$N_1V_1 + N_2V_2 + N_3V_3 = N_{mix}V_{mix}$

$1.1 \times 10^{-2} + 1 \times 10^{-4} + 1 \times 10^{-5} = N_{mix} \times 3$

$N_{mix} = 0.37 \times 10^{-3}$

$[H^+] = 3.7\times10^{-4}$ M

71. (a) Given, $[H_3O^+] = 1 \times 10^{-10}$ M

At 25°C, $[H_3O^+][OH^-] = 10^{-14}$

$\therefore [OH^-] = \frac{10^{-14}}{10^{-10}} = 10^{-4}$

Now, $[OH^-] = 10^{-4}$, $pOH = -\log[OH^-] = -\log[10^{-4}]$

pOH = 4

72. (a) Given, $K_a = 1.00 \times 10^{-5}$, C = 0.100 mol for a weak electrolyte, degree of dissociation (α) is:

$\alpha = \sqrt{\frac{K_a}{C}} = \sqrt{\frac{1\times10^{-5}}{0.100}} = 10^{-2} = 1\%$

73. (b) HCl completely ionises and thus $[H^+] = 1 \times 10^{-8}$ m. The concentration is very low and thus self ionization of water must be considered that is:

$H_2O(l) \rightleftharpoons H^+(aq) + \bar{O}H(aq)$

Assuming that H_2O ionises to give 'y' M of H^+ and 'y' M of OH^- ions as:

$K_w = [H^+][OH^-]$

$[y + (1 \times 10^{-8})]\ y = 1 \times 10^{-14}$

On solving, $y = 9.51 \times 10^{-8}$

$[H^+] = (1 \times 10^{-8}) + (9.51 \times 10^{-8}) = 1.0525 \times 10^{-7}$ M

74. (b) NH_4OH is a weak base but HCl is a strong acid in solution, so pH of NH_4Cl solution is comparatively low.

$NaNO_3$ is a salt of strong base and strong acid, so pH of the solution will be 7.

Hydrolysis of potassium acetate (a salt of a weak acid and a strong alkali) gives a weakly alkaline solution, since the acetate ion acts as a weak base.

$CH_3COOK + H_2O \rightarrow CH_3COOH + K^+ + OH^-$

The pH of this solution ≈ 8.8.

Hydrolysis of sodium carbonate (a salt of strong alkali and a weak acid) gives an alkaline solution.

$Na_2CO_3 + 2H_2O \rightarrow 2(Na^+ + OH^-) + H_2CO_3$

The pH of this solution is > 10.

75. (d) $C = 0.01$ M

$K_b = 1 \times 10^{-12}$ at 25°C

Initial	$BOH \rightleftharpoons$	$B^+ +$	OH^-
	C	0	0
At equilibrium	$C - C\alpha$	$C\alpha$	$C\alpha$

$[OH^-] = C\alpha$

$$[OH^-] = \sqrt{K_b C} = \sqrt{1\times10^{-12}\times10^{-2}}$$

$[OH^-] = 10^{-7}$ mol $L^{-1} = 1 \times 10^{-7}$ mol L^{-1}

76. (b)

N_2	+ $2H_2$	$\rightleftharpoons$	$2NH_3$
1	3		2
10L	30L		10L

As only 50% of the expected product is formed, hence only 10L of NH_3 is formed.

Thus for production of 10L of NH_3, 5L of N_2 and 15L of H_2 are used and composition of gaseous mixture under given condition in the end is:

$H_2 = 30 - 15 = 15$ L

$N_2 = 30 - 15 = 25$ L

$NH_3 = 10$ L

77. (d) $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$

$$K_{ion} = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$$

$$[CH_3COOH] = \frac{3.4\times10^{-4}\times3.4\times10^{-4}}{1.7\times10^{-5}}$$

$$= 6.8 \times 10^{-3}$$

78. (b) (i) $H_2A \overset{Ka_1}{\rightleftharpoons} HA + H^+$

(ii) $HA \overset{Ka_2}{\rightleftharpoons} A^{2-} + H^+$

In the 1st step, H^+ ion comes from neutral molecules, while in the 2nd step, the H^+ ion comes from negatively charged ions. The presence of negative charge makes the removal H^+ ion difficult. Thus, $K_{a_1} > K_{a_2}$

79. (b) On adding CH_3COOH (weak acid) and NaOH (strong base), after neutralisation, the salt (CH_3COONa) formed dissociates in water giving free OH^- ions. Thus, pH will be greater than 7.

80. (c) For monobasic acid

= Molarity × Degree of ionisation

$$[H]^+ \Rightarrow 0.1\times\frac{2}{100} = 2\times10^{-3}\text{M}$$

$$[OH^-] = \frac{K_w}{[H^+]} = \frac{1\times10^{-14}}{2\times10^{-3}}$$

$= 5 \times 10^{-12}$ M

81. (c) Ammonium sulphate is a salt of weak base or strong acid. The aqueous solution of ammonium sulphate is acidic. So, it produced acidity.

82. (d) Value of K_w depends on temperature. At high temperature, the value of ionic product increases.

83. (c) $2HI \rightarrow H_2 + I_2$

2	0	0
$2-2\alpha$	α	α

Total moles $= 2 - 2\alpha + 2\alpha$

$= 2$

84. (b) Since, NaOH is a strong base, therefore it completely ionises. Thus, the hydroxyl ion concentration is equal to that of the base itself. We know that concentration of OH^- in N/10 NaOH = 0.1 = 10^{-1}. Therefore value of $[H_3O^+]$ will be equal to:

$$[H_3O^+] = \frac{K_w}{[OH^-]} = \frac{1\times10^{-14}}{10^{-1}}$$

$= 1 \times 10^{-13}$ or pH = – log $[H_3O^+]$

$= -\log[1 \times 10^{-13}] = 13$

85. (c) Since HCl is a strong acid and it completely ionises, therefore H_3O^+ ions concentration is equal to the acid itself *i.e.* $[H_3O^+] = [HCl] = 10$ M

Therefore, pH = –log $[H_3O^+]$ = –log [10] = –1

86. (a) $[H_3O^+] = [OH^-] = 1 \times 10^{-6}$ mole L^{-1}

$K_w = [H_3O^+][OH^-] \Rightarrow [1 \times 10^{-6}] \times [1 \times 10^{-6}]$

$= 1 \times 10^{-12}$

87. (a) Sodium borate is a salt formed from strong base (NaOH) and weak acid (H_3BO_3). Hence, sodium borate will act basic.

88. (b) $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$

89. (c) NH_4Cl and $NaHCO_3$ are acidic in nature and NaCl is neutral. Only Na_2CO_3 is basic and thus, have highest pH.

90. (a) The formation of acidic buffer takes place by mixing weak acid and its salt with strong base.

91. (b) Acidic buffer is formed when a weak acid is mixed with its salt with a strong base. According to Henderson equation, pH of acidic buffer is calculated as:

$$pH = pK_a + \log\frac{[salt]}{[acid]}$$

Substitute the given values in above equation as:

$$= 4.57 + \log\frac{[0.10]}{[0.01]}$$

$= 4.57 + [\log 10 - \log 1]$

$= 4.57 + (1 - 0)$

$= 4.57 + (1)$

$= 5.57$

92. (c) A basic buffer is prepared by mixing weak base and its salt with strong acid.

a. $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$

Initial	25 mL × 0.1 M = 2.5 m mol	50 mL × 0.1M = 5 m mol	0
Final	0	2.5 m mol	2.5 m mol

This is basic solution due to NaOH.

This is not basic buffer.

b. $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$

Initial	100 mL × 0.1 M = 10 m mol	100 mL × 0.1 M = 10 m mol	0
Final	0	0	10 m mol

Hydrolysis of salt takes place.

This is not basic buffer.

c. $HCl + NH_4OH \rightarrow NH_4Cl + H_2O$

Initial	100 mL × 0.1 M = 10 m mol	200 mL × 0.1 M = 20 m mol	0
Final	0	10 m mol	10 m mol

This will make basic buffer.

d. $HCl + NaOH \rightarrow NaCl + H_2O$

Initial	100 mL × 0.1 M = 10 m mol	100 mL × 0.1 M = 10 m mol	0
Final	0	0	10 m mol

$\Rightarrow$ This is neutral solution.

93. **(b)** $HClO_4$ and $NaClO_4$ will not make a buffer solution because a buffer solution is formed by the mixture of a weak acid and its conjugate base and $HClO_4$ is not a weak acid.

94. **(b)** If small amount of an acid or alkali is being added to a buffer solution, it converts them into unionised acid or base. Therefore, its pH remains unaffected.

$H_3O^+ + A^- \rightleftharpoons H_2O + HA$

$OH^- + HA \rightleftharpoons H_2O + A^-$

If acid is added, it will react with A^- which results int he formation of HA. In a similar manner, if base is added, then OH^- will combine with HA to give H_2O and A^- due to which acidity / alkalinity of buffer solution will be maintained.

95. **(b)** It's a Basic Buffer

So;

$$pOH = pK_b + \log \frac{[salt]}{[base]}$$

$$pOH = 4.74 + \log\left(\frac{0.2}{0.3}\right) = 4.56 \qquad (pK_b = -\log K_b)$$

$$pH = 14 - pOH = 9.43$$

96. **(a)** $HB \rightleftharpoons H^+ + B^-$

$$pOH = pK_b + \log \frac{[B^-]}{[HB]}$$

$K_b = 10^{-10}$

(Concentration of $[B^-] = [HB]$)

So, $pOH = pK_b$

$\Rightarrow pOH = 10$

$\therefore pH = 14 - 10 = 4$

97. **(a)** Buffer solutions are made by mixing of a weak acid/base with its strong conjugate base/acid. These solutions resist the change in pH. HNO_2 is a weak acid and $NaNO_2$ is its strong conjugate base, this mixture constitutes a buffer.

98. **(c)** Henderson Hasselbalch equation in terms of HIn and In^- is:

$$pH = pK_{In} + \log \frac{[In^-]}{[HIn]}$$

$$\log \frac{[In^-]}{[HIn]} = pH - pK_{In}$$

99. **(b)** According to Henderson equation:

$$pOH = pK_b + \log \frac{[Salt]}{[Base]}$$

$$pK_b = pOH - \log \frac{[Salt]}{[Base]}$$

$$= (14 - pH) - \log \frac{[0.1]}{[0.1]}$$

$$pK_b = 14 - 9.25 - \log \frac{[0.1]}{[0.1]}$$

$$pK_b = 4.75$$

100. **(b)** $pH = pK_a + \log \frac{[Salt]}{[Acid]}$

For maximum buffer capacity $[Salt]/[Acid] \approx 1$

$pH = pK_a + \log 10^1$

$pH = pK_a$

Therefore, pK_a should be 3.58.

101. **(d)** The pH value of the blood is maintained constant by buffer solution present in the blood itself. Buffer solutions resist the change in pH values.

102. **(d)** Let the solubility of $Ni(OH)_2$ is s.

$$Ni(OH)_2 \rightleftharpoons Ni^{2+} + 2OH^-$$

s s 2s

Dissociation of NaOH is:

$NaOH \rightarrow Na^+ + OH^-$

0.1 0.1 0.1

As K_{sp} is small, $2s << 0.10$

Therefore, $(0.10 + 2s) \approx 0.10$

So, Total $[OH]^- = 0.10$

Ionic product $= [Ni^{2+}][OH^-]^2$

$2 \times 10^{-15} = s(0.10)^2$

On solving,

$s = 2 \times 10^{-13}$ M

103. **(a)** The addition of an ion into a solution having two or more solutes reduces the ionization provided the ion will be common to both the solutes is known as common ion effect. Because of the presence of this common ion, precipitation takes place.

When HCl is passed through the mixture of $CaCl_2$, $MgCl_2$ and NaCl, Cl^- ion concentration increases. As $CaCl_2$ and $MgCl_2$ are more soluble than NaCl.

Hence, ionic product $[Na^+]\,[Cl^-]$ becomes more than solubility product. Thus, precipitation of NaCl occurs (due to common ion effect).

104. (d) For salt AB:

$AB \rightleftharpoons A^+ + B^-$

Let s be the solubility of salt AB, so,

$AB \rightleftharpoons A^+ + B^-$

s s

$K_{sp} = (s)^2$

$s = \sqrt{K_{sp}}$

$s = \sqrt{4\times10^{-8}}$

$s = 2 \times 10^{-4}$ M

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105. (a) Dissociation of $Ca(OH)_2$ can be represented as:

$Ca(OH)_2 \rightleftharpoons Ca^{2+} + 2OH^-$

$pH + pOH = 14$

pH= 9, thus $pOH = 14 - 9 = 5$

$[OH^-] = 10^{-5}$ M

Thus, $[Ca^{2+}] = \frac{10^{-5}}{2}$ (1 mol Ca^{2+} = 2 mol OH^-)

So, $K_{sp} = [Ca^{2+}][OH^-]^2$

$= \frac{10^{-5}}{2}(10^{-5})^2$

$= 0.5 \times 10^{-15}$

106. (a) Solubility in mol L^{-1} is obtained by dividing the solubility of salt in g/L with its molar mass. Solubility of $BaSO_4$:

$s = \frac{2.42\times10^{-3}}{233}(\text{mol L}^{-1})$

$= 1.04 \times 10^{-5}$ (mol L^{-1})

Dissociation reaction of $BaSO_4$ can be written as:

$BaSO_4(s) \rightleftharpoons \underset{s}{Ba^{2+}}(aq) + \underset{s}{SO_4^{2-}}(aq)$

$K_{sp} = [Ba^{2+}]\,[SO_4^{2-}] = s^2$

$= (1.04 \times 10^{-5})^2$

$= 1.08 \times 10^{-10}$ mol^2 L^{-2}

107. (a) Dissociation of $Ag_2C_2O_4$ can be represented as:

$Ag_2C_2O_4 \rightarrow 2Ag^+ + C_2O_4^{2-}$

2s s

Now,

$K_{sp} = [Ag^+]^2\,[C_2O_4^{2-}]$

$= (2s)^2$ (s); ($[Ag^+] = 2.2 \times 10^{-4}$])

$= (2.2 \times 10^{-4})^2 (1.1 \times 10^{-4})$ $[2s = 2.2 \times 10^{-4}]$

$= 4.84 \times 10^{-8} \times 1.1 \times 10^{-4}$

$= 5.3 \times 10^{-12}$

108. (d) Follow the steps

	$NaCl(aq)$	$\rightleftharpoons$	Na^+	Cl^-
Initially	0.1M		0	0
At equilibrium	0		0.1	$0.1 + s$

	$AgCl$	$\rightleftharpoons$	Ag^+	+	Cl^-
Initially	a		0		0
At equilibrium	0		s		$0.1 + s$

The expression of solubility product (K_{sp}) is:

$K_{sp} = 1.6 \times 10^{-10} = [Ag^+]\,[Cl^-] = s\,(0.1 + s)$

Value of K_{sp} is very small, so,

$0.1 + s \approx 0.1$

$1.6 \times 10^{-10} = s \times 0.1$

$s = 1.6 \times 10^{-9}$ M

109. (c) Let solubility be s.

For $MY \rightleftharpoons M^+ + Y^-$

s s

$K_{sp} = 6.2 \times 10^{-13}$

$K_{sp} = s^2$

$s = \sqrt{K_{sp}}$

$= \sqrt{6.2\times10^{-13}}$

$= 7.9 \times 10^{-7}$ mol L^{-1}

For $NY_3 \rightleftharpoons N^{3+} + 3Y^-$

s 3s

$K_{sp} = s(3s)^3$

$K_{sp} = 27s^4 \Rightarrow s = \left(\frac{K_{sp}}{27}\right)^{1/4}$

$s = \left(\frac{6.2\times10^{-13}}{27}\right)^{1/4}$

$s = 3.89 \times 10^{-4}$ mol L^{-1}

So, solubility of NY_3 is more than solubility of MY in pure water and addition of KY decrease the solubility because of common ion effect.

110. (c) Let solubility of salt be s.

$Ag_2CrO_4 \rightleftharpoons 2Ag^+ + CrO_4^{2-}$

2s s

$K_{sp} = (2s)^2 s = 4s^3$

$s = \left(\frac{K_{sp}}{4}\right)^{1/3} = \left(\frac{1.1\times10^{-12}}{4}\right)^{1/3} = 0.65\times10^{-4}$

$AgCl \rightleftharpoons Ag^+ + Cl^-$

s s

$K_{sp} = s^2$

$s = \sqrt{K_{sp}} = \sqrt{1.8\times10^{-10}} = 1.34\times10^{-5}$

$AgBr \rightleftharpoons Ag^+ + Br^-$

s s

$K_{sp} = s^2$

$s = \sqrt{K_{sp}} = \sqrt{5.0\times10^{-13}} = 0.71\times10^{-6}$

$AgI \rightleftharpoons Ag^+ + I^-$

s s

$K_{sp} = s^2$

$s = \sqrt{K_{sp}} = \sqrt{8.3\times10^{-17}} = 0.9\times10^{-8}$

From the above calculations, it is clear that Ag_2CrO_4 has the highest solubility, so, it will be precipitated at last.

111. (b) The relation between ΔG° and $\log K_{sp}$ is.

$\because \Delta G^\circ = -2.303\ RT \log K_{sp}$

Substitute the given values in above equation as:

$63.3 \times 10^3 J = -2.303 \times 8.314 \times 298 \log K_{sp}$

$K_{sp} = 8.128 \times 10^{-12}$

112. (b) Salts of sodium are highly soluble in water because Na^+ can easily create a hydration sphere around the ion as compared to other ions. Solubility product of CuS is less than that of ZnS which means that ZnS is more soluble. Hence, the correct order is:

$Na_2S > ZnS > CuS$

113. (c) pH = 12 of $Ba(OH)_2$

pOH = 2

Let x be the solubility of $Ba(OH)_2$.

$Ba(OH)_2 \rightleftharpoons Ba^{2+} + 2OH^-$

x 2x

$2x = 10^{-2}$

$x = 5 \times 10^{-3}$

$K_{sp} = (x)(2x)^2 = 5 \times 10^{-7}$

114. (a) $AgCl \rightleftharpoons Ag^+ + Cl^-$

$K_{sp} = [Ag^+][Cl^-]$

$[Ag^+] = \frac{1.8 \times 10^{-10}}{0.10}$

$[Ag^+] = 1.8 \times 10^{-9}\ M$

$PbCl_2 \rightleftharpoons Pb^{2+} + 2Cl^-$

$K_{sp} = [Pb^{2+}][Cl^-]^2$

$[Pb^{2+}] = \frac{1.7 \times 10^{-5}}{0.10 \times 0.10}$

$[Pb^{2+}] = 1.7 \times 10^{-3}\ M$

115. (a) pH of $Ba(OH)_2 = 12$

pH = 12

So, pOH = 2

$[OH^-] = 10^{-2}$

Let s be the solubility of $Ba(OH)_2$.

$Ba(OH)_2 \rightleftharpoons Ba^{2+} + 2OH^-$

s 2s

As, $2s = 10^{-2}$

$s = 5 \times 10^{-3}\ M$

$K_{sp} = [5 \times 10^{-3}][10^{-2}]^2$

$K_{sp} = 5 \times 10^{-7}\ M^3$

116. (a) The cation of group II are precipitated as their sulphides.

- Solubility product of sulphide of group II radicals are very low.
- Therefore, even with low concentration of S^{2-} ions, the ionic product exceeds the value of their solubility product and the radical of group II gets precipitated.
- The low concentration of S^{2-} ions is obtained by passing H_2S gas through the solution of the salt in the presence of dil. HCl which suppresses degree of ionisation of H_2S by common ion effect.

$H_2S \rightleftharpoons 2H^+ + S^{2-}$

$HCl \rightleftharpoons H^+ + Cl^-$

common ion is H^+

- Solubility product of group IV radicals are quite high.
- It is necessary to suppress the concentration of S^{2-} ions otherwise radical of group IV will also get precipitated along with group II radicals.

117. (b) $K_{sp} = 3.2 \times 10^{-11}$

Let solubility of AX_2 be s.

$AX_2 \rightleftharpoons A^{2+} + 2X^-$

$K_{sp} = s \times (2s)^2 = 4s^3$

$4s^3 = 3.2 \times 10^{-11}$

$s^3 = 0.8 \times 10^{-11}$

$\therefore s = 2 \times 10^{-4}$

118. (b) $AgI \rightleftharpoons Ag^+ + I^-$

$1.0 \times 10^{-16} = s \times s$

Solubility of $Ag^+ = 1.0 \times 10^{-8}\ mol\ L^{-1}$

Solubility of AgI in KI solution

$= 1.0 \times 10^{-8} \times 10^{-4} = 1.0 \times 10^{-12}\ mol\ L^{-1}$

119. (d) Lets s be the solubility of MX_2.

$MX_2 \rightleftharpoons M^{2+} + 2X^-$

s 2s

$K_{sp} = s(2s)^2 = 4s^3$

$= 4 \times (0.5 \times 10^{-4})^3 = 5 \times 10^{-13}$

120. (b) For reaction:

$M_2S \rightleftharpoons 2M^+ + S^{2-}$

Solubility $= 3.5 \times 10^{-6}$

Solubility product, $K_{sp} = [M^+]^2[S^{2-}]$

$= (2s)^2 s = 4s^3 = 4 \times (3.5 \times 10^{-6})^3 = 1.7 \times 10^{-16}$

121. (d) Let s be the solubility of CaF_2.

Dissociation reaction of CaF_2 is:

$CaF_2 \rightleftharpoons Ca^{2+} + 2F^-$

K_{sp} of $CaF_2 = [Ca^{2+}][F^-]^2$

$= [2 \times 10^{-4}][4 \times 10^{-4}]^2 = 32 \times 10^{-12}\ mol/L^2$

122. (b) The greater the solubility product, the greater is the solubility. Hence, the correct order is given in option (b).

123. (a) The concentration of common ion i.e., Cl^- is maximum in 0.01 M $CaCl_2$. Therefore, it would suppress the ionisation of AgCl and the solubility would be least.

124. (d) Higher the value of solubility product, greater is the solubility.

$K_{sp} \propto s$

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CHAPTER 7

Redox Reactions

Redox Reactions (Oxidation and Reduction), Oxidation Number

1. The **correct** option for a redox couple is: *(2023-Manipur)*

a. Both are oxidised forms involving same element.

b. Both are reduced forms involving same element.

c. Both the reduced and oxidized forms involve same element.

d. Cathode and anode together.

2. What is the change in oxidation number of carbon in the following reaction? *(2020)*

$CH_4(g) + 4Cl_2(g) \rightarrow CCl_4(l) + 4HCl(g)$

a. 0 to + 4 b. –4 to – 4

c. 0 to –4 d. +4 to + 4

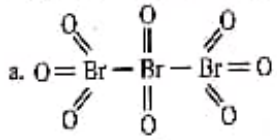
3. The oxidation number of the underlined atom in the following species [MR$^{\Delta}$] *(2020-Covid)*

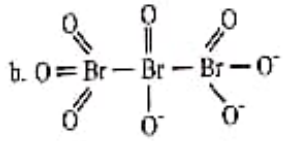
a. $\underline{Cl}O_3^-$ is +5 b. $K_2\underline{Cr}_2O_7$ is –6

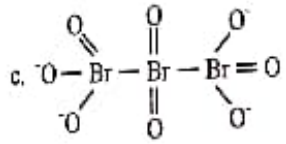
c. $HA\underline{u}Cl_4$ is +3 d. $\underline{Cu}_2O$ is –1

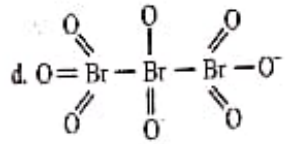
Identify the incorrect option

4. The correct structure of tribromooctaoxide is *(2019)*

a. 

b. 

c. 

d. 

5. Hot concentrated sulphuric acid is a moderately strong oxidising agent. Which of the following reactions does not show oxidising behaviour? [MR$^{\Delta}$] *(2016 - I)*

a. $C + 2H_2SO_4 \rightarrow CO_2 - 2SO_2 + 2H_2O$

b. $CaF_2 + H_2SO_4 \rightarrow CaSO_4 + 2HF$

c. $Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2H_2O$

d. $3S + 2H_2SO_4 \rightarrow 3SO_2 + 2H_2O$

6. In acidic medium, H_2O_2 changes $Cr_2O_7^{-2}$ to CrO_5 which has two (—O—O—) bonds. Oxidation state of Cr in CrO_5 is: *(2014)*

a. +3 b. +6

c. –10 d. +5

7. The pair of compounds that can exist together is *(2014)*

a. $FeCl_3$, $SnCl_2$ b. $HgCl_2$, $SnCl_2$

c. $FeCl_2$, $SnCl_2$ d. $FeCl_3$, KI

8. The oxidation state of Cr in CrO_3 is *(2014)*

a. –6 b. +12

c. +6 d. +4

9. A mixture of potassium chlorate, oxalic acid and sulphuric acid is heated. During the reaction, which element undergoes maximum change in the oxidation number? *(2012 Pre)*

a. C b. S

c. H d. Cl

10. In which of the following compounds, nitrogen exhibits highest oxidation state? *(2012 Pre)*

a. NH_2OH b. N_2H_4

c. NH_3 d. N_3H

11. The oxide, which cannot act as a reducing agent is: *(2010 Pre, 1995)*

a. CO_2 b. ClO_2

c. NO_2 d. SO_2

12. Oxidation numbers of P in PO_4^{3-}, of S in SO_4^{2-} and that of Cr in $Cr_2O_7^{3-}$, are respectively: *(2009)*

a. +3, +6 and +5 b. +5, +3 and +6

c. –3, + 6 and +6 d. +5, +6 and +6

13. Which is the best description of the behaviour of bromine in the reaction given below: *(2004)*

$H_2O + Br_2 \rightarrow HOBr + HBr$

a. Both oxidised and reduced

b. Oxidised only

c. Reduced only

d. Proton acceptor only

a. $\frac{3}{2}$ b. $\frac{4}{5}$

c. $\frac{5}{4}$ d. $\frac{8}{3}$

15. In which of the following compounds, transition metal has zero oxidation state? *(1999)*

a. $[Fe(CO)_5]$ b. $NH_2\text{-}NH_2$

c. $NOClO_4$ d. CrO_5

16. Which of the following is redox reaction? *(1997)*

a. Evaporation of H_2O

b. Both oxidation and reduction

c. H_2SO_4 with NaOH

d. In atmosphere O_3 from O_2 by lighting

17. Which substance is serving as a reducing agent in the following reaction? **[MR*]** *(1994)*

$14H^+ + Cr_2O_7^{2-} + 3Ni \rightarrow 7H_2O + 3Ni^{2+} + 2Cr^{3+}$

a. H^+ b. $Cr_2O_7^{2-}$

c. H_2O d. Ni

18. The oxidation state of I in $H_4IO_6^-$ is: *(1994)*

a. +1 b. –1

c. +7 d. +5

Types of Redox Reactions and Balancing of Redox Reactions

19. On balancing the given redox reaction, **[MR*]** *(2023)*

$aCr_2O_7^{(2-)} + bSO_3^{(2-)}(aq) + cH^+(aq) \rightarrow$

$2aCr^{3+}(aq) + bSO_4^{2-}(aq) + c/2\ H_2O(l)$

the coefficients a, b and c are found to be, respectively:

a. 8, 1, 3 b. 1, 3, 8

c. 3, 8, 1 d. 1, 8, 3

20. Which of the following reactions is a decomposition redox reaction? *(2022 Re)*

a. $P_4(s) + 3OH^-(aq) + 3H_2O(l) \rightarrow PH_3(g) + 3H_2PO_2^-(aq)$

b. $2\ Pb(NO_3)_2(s) \rightarrow 2PbO(s) + 4NO_2(g) + O_2(g)$

c. $N_2(g) + O_2(g) \rightarrow 2NO(g)$

d. $Cl_2(g) + 2OH^-(aq) \rightarrow ClO^-(aq) + Cl^-(aq) + 4H_2O(l)$

21. Which of the following reactions is the metal displacement reaction? Choose the right option. *(2021)*

a. $Cr_2O_3 + 2Al \xrightarrow{\Delta} Al_2O_3 + 2Cr$

b. $Fe + 2HCl \longrightarrow FeCl_2 + H_2\uparrow$

c. $2Pb(NO_3)_2 \longrightarrow 2PbO + 4NO_2 + O_2\uparrow$

d. $2KClO_3 \xrightarrow{\Delta} 2KCl + 3O_2$

22. Which of the following reactions are disproportionation reaction? **[MR*]** *(2019)*

A. $2Cu^+ \longrightarrow Cu^{2+} + Cu^0$

B. $3MnO_4^{2-} + 4H^+ \longrightarrow 2MnO^-_4 + MnO_2 + 2H_2O$

C. $2KMnO_4 \xrightarrow{\Delta} K_2MnO_4 + MnO_2 + O_2$

D. $2MnO_4^- + 3Mn^{2+} + 2H_2O \longrightarrow 5MnO_2 + 4H^{\oplus}$

Select the correct option from the following

a. (A) and (B) only b. (A), (B) and (C)

c. (A), (C) and (D) d. (A) and (D) only

23. For the redox reaction

$MnO_4^- + C_2O_4^{2-} + H^+ \rightarrow Mn^{2+} + CO_2 + H_2O$

The correct coefficients of the reactants for the balanced equation are: *(2018)*

	MnO_4^-	$C_2O_4^{2-}$	H^+
a.	16	5	2
b.	2	5	16
c.	5	16	2
d.	2	16	5

24. Number of moles of MnO_4^- required to oxidize one mole of ferrous oxalate completely in acidic medium will be: *(2008)*

a. 0.2 moles b. 0.6 moles

c. 0.4 moles d. 7.5 moles

Redox Reactions and Electrode Processes

25. Standard electrode potential of three metals X, Y and Z are –1.2 V, +0.5 V and –3.0 V respectively. The reducing power of these metals will be: **[MR*]** *(2011 Pre)*

a. X > Y > Z b. Y > Z > X

c. Y > X > Z d. Z > X > Y

26. On electrolysis of dilute sulphuric acid using platinum electrodes, the product obtained at the anode will be: *(1992)*

a. Hydrogen b. Oxygen

c. Hydrogen sulphide d. Sulphur dioxide

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Answer Key

1. (c)	2. (b)	3. (d)	4. (a)	5. (b)	6. (b)	7. (c)	8. (c)	9. (d)	10. (d)
11. (a)	12. (d)	13. (a)	14. (d)	15. (a)	16. (b)	17. (d)	18. (c)	19. (b)	20. (b)
21. (a)	22. (a)	23. (b)	24. (c)	25. (d)	26. (b)				

Explanations

1. (c) In redox couple, both the reduced and oxidised form involve same element.

2. (b) $CH_4(g) + 4Cl_2(g) \rightarrow CCl_4(l) + 4HCl(g)$

In the given reaction:

Let oxidation number of Carbon be x.

H has + 1 oxidation number.

In CH_4:

$x + 4 \times 1 = 0$

$x = -4$

In CCl_4:

Cl oxidation state is –1.

$x + 4 \times (-1) = 0$

$x = +4$

Thus, change in oxidation state of carbon is from –4 to +4.

3. (d) (a) $\underline{Cl}O_3^-$

Let oxidation state of Cl be x.

$x + 3(-2) = -1$

$x = +5$

(b) $K_2\underline{Cr}_2O_7$

Let oxidation state of Cr be x.

$2(+1) + 2x + 7(-2) = 0$

$x = +6$

(c) $H\underline{Au}Cl_4$

Let oxidation state of Au be x.

$(+1) + x + 4(-1) = 0$

$x = +3$

(d) $\underline{Cu}_2O$

Let oxidation state of O be x.

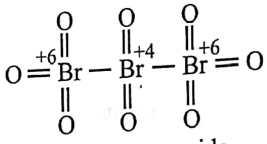
$2(+1) + x = 0$

$x = -2$

4. (a) Tribromooctaoxide is a neutral molecule and does not contain any charge. This structure contains all oxygen atoms bonded with double bonds with bromine atoms. It contains three Bromine atoms and eight O atoms. Two terminal Br atoms will make bond with three O atoms and a Br-Br bond.

The oxidation no of bromine is $\frac{16}{3}$ in this structure.

The correct structure of Br_3O_8 is:

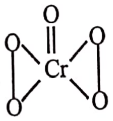


Tribromooctaoxide

5. (b) $\overset{+2\ -1}{CaF_2} + \overset{+1\ +6\ -2}{H_2SO_4} \rightarrow \overset{+2\ +6\ -2}{CaSO_4} + \overset{+1\ -1}{2HF}$

This reaction is not a oxidation reaction as none of the atom in the reaction is showing any change in the oxidation number. H_2SO_4, here in the reaction is not acting as a reducing nor an oxidising agent.

6. (b) CrO_5 has a very famous butterfly structure containing two peroxo bonds. Oxygen in peroxide has -1 oxidation state. It can be represented as:



Let oxidation state of Cr be x.

$x + 4(-1) + 1(-2) = 0$

$x = +6$

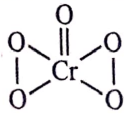
7. (c) Compounds having lower oxidation number and those which cannot be reduced by one another can exist together.

Both $FeCl_2$ and $SnCl_2$ are reducing agents with low oxidation numbers.

$Fe^{2+} + Sn^{2+} \rightarrow$ No reaction

8. (c) CrO_5 has butterfly structure having two peroxo bonds.

Peroxo oxygen has –1 oxidation state.



Let oxidation state of Cr be 'x'.

$CrO_5 : x + 4(-1) + 1(-2) = 0 \Rightarrow x = +6$

9. (d) The reaction between given species can be written as:

$KClO_3 + H_2C_2O_4 + H_2SO_4 \xrightarrow{\Delta} K_2SO_4 + KCl + CO_2$

Oxidation No. of different Elements	Reactant side	Product side
S	+6	+6
C	+3	+1
Cl	+4	–1

Change in O.N. of 'S' = 0 (6 – 6)
Change in O.N. of 'C' = 1 (4 – 3)
Change in O.N. of 'Cl' = 5 (4 – (–1))
So, 'Cl' is going maximum change in oxidation number.

10. (d) Let oxidation state of N be x.
So, oxidation state of N in $N_3H = -1/3$
$NH_2OH = x + 2 - 1 = -1$
$N_2H_4 = 2x + 4 = -2$
$NH_3 = -3$
∴ In N_3H, N is present in its highest oxidation state.

11. (a) When an element is present in its maximum oxidation state, it cannot be oxidized further which means it cannot act as a reducing agent. Since carbon is in maximum state of +4, therefore carbon dioxide (CO_2) cannot act as a reducing agent.

12. (d) Let x be the oxidation state of P, S and Cr respectively in the following cases:

PO_4^{3-} $\quad x + [4 \times (-2)] + (-3) = 0$
$x = 5$

SO_4^{2-} $\quad 2x + 14 - 2 = 0$
$x = 6$

$Cr_2O_7^{2-}$ $\quad x + (8 - 2) = 0$
$x = 6$

Oxidation state of PO_4^{3-} is 5, SO_4^{2-} is 6 and $Cr_2O_7^{2-}$ is 6.

13. (a) $H_2O + \overset{0}{Br_2} \rightarrow \overset{+1}{HOBr} + \overset{-1}{HBr}$

In Br_2, Br has 0 oxidation state, in HOBr, it has +1 oxidation state and in HBr, it has –1 oxidation state. Thus, Br_2 is oxidised as well as reduced hence, it is a redox reaction.

14. (d) Let oxidation state of Fe be x.
$x = -2$
In Fe_3O_4:
$3x + (-2 \times 4) = 0$
$3x = +8$
$x = +8/3$

15. (a) CO is a neutral ligand due to which complex as a whole has 0 charge. Oxidation state of Fe in $Fe(CO)_5$ is zero.

16. (b) Redox reactions are those chemical reactions which involve transfer of electrons from one chemical species to another. In this reaction, both reduction and oxidation takes place simultaneously.

17. (d) $14H^+ + \overset{+6}{Cr_2O_7^{2-}} + 3\overset{0}{Ni} \rightarrow \overset{-2}{7H_2O} + 3\overset{+2}{Ni^{2+}} + 2\overset{+3}{Cr^{3+}}$

On reactant side, Ni has 0 oxidation state and on product side, it has +2 oxidation state. Ni is getting oxidized from 0 to +2 Oxidation state.

Since the oxidation number of Ni increases from 0 to 2, therefore, it acts as a reducing agent.

18. (c) Let x = Oxidation state of I. Since oxidation state of H = +1 and oxidation state of O = –2. Therefore, for $H_4IO_6^-$,
$(4 \times 1) + x + (6 \times -2) = -1$ or $x = +7$

19. (b) Reduction half reaction.
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{+3} + 7H_2O$ ... (i)
Oxidation half reaction
$SO_3^{2-} + H_2O \rightarrow SO_4^{2-} + 2e^-]\times 3$ ... (ii)
Oxygen is balanced by adding water and hydrogen is balanced by adding H^+ and the charge is balanced by electrons.
Add(eq. (i)) + (3 × eq. (ii))
$Cr_2O_7^{2-} + 3SO_3^{2-} + 8H^+ \rightarrow 2Cr^{+3} + 3SO_4^{2-} + 4H_2O$
a = 1 b = 3 c = 8

20. (b) In reaction (2), lead nitrate, $Pb(NO_3)_2$ decomposed to give PbO, NO_2 and O_2. In this reaction, the oxidation state of Nitrogen changes from +5 to +4 and that of oxygen changes from –2 to zero.

21. (a) (a) $Cr_2O_3 + 2Al \xrightarrow{\Delta} Al_2O_3 + 2Cr$

(b) $Fe + 2HCl \rightarrow FeCl_2 + H_2\uparrow$

Both are examples of displacement reactions. But, reaction in option (a) is an example of metal displacement reaction (Al displaces Cr from Cr_2O_3).

(c) $2Pb(NO_3)_2 \rightarrow 2PbO + 4NO_2 + O_2\uparrow$

This reaction is an example of decomposition reaction.

(d) $2KClO_3 \xrightarrow{\Delta} 2KCl + 3O_2$

This reaction is also an example of thermal decomposition reaction.

22. (a) Disproportionation Reaction: In this reaction, same element undergoes oxidation and reduction simultaneously.

A. $\overset{+1}{2Cu^+} \longrightarrow \overset{+2}{Cu^{2(+)}} + \overset{0}{Cu}$ Disproportionation
(red: $Cu^+ \rightarrow Cu$; oxd: $Cu^+ \rightarrow Cu^{2+}$)

B. $\overset{+6}{3MnO_4^{2(-)}} + 4H^{(+)} \longrightarrow \overset{+7}{2MnO_4^-} + \overset{+4}{MnO_2}$
(red: $Mn^{+6} \rightarrow Mn^{+4}$; oxd: $Mn^{+6} \rightarrow Mn^{+7}$) $+2H_2O$ Disproportionation

C. $\overset{+7}{2KMnO_4^-} \longrightarrow \overset{+6}{K_2MnO_4} + \overset{+4}{MnO_2} + \overset{0}{O_2}$ ∴
not a disproportionation

D. $\overset{+7}{MnO_4} + 3\overset{+2}{Mn^{2+}} + 2H_2O \longrightarrow 5\overset{+4}{MnO_2} + 4H^{\oplus}$
not a disproportionation

23. (b) First balance C atoms:
$\overset{+7}{MnO_4^-} + \overset{+3}{C_2O_4^{2-}} + H^+ \rightarrow \overset{+2}{Mn^{2+}} + 2\overset{+4}{CO_2} + H_2O$
Balance Mn atoms as:
$2MnO_4^- + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 10CO_2$
Balance O atoms by adding $8H_2O$ to the products side:
$2MnO_4^- + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$
Balance H atoms by adding $16H^+$ to the reactants side:
$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$

24. (c) According to chemical equation:

$FeC_2O_4 \rightarrow Fe^{+2} + 2CO_2 + 2e^-\}\times 5$

$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O\}\times 2$

Comparing equation (1) and (2):

$5FeC_2O_4 + 2MnO_4^- + 16H^+ \rightarrow 2Mn^{2+} + 5Fe^{2+} + 10CO_2 + 12H_2O$

Accordingly, 5 moles of FeC_2O_4 requires 2 moles of MnO_4^-.

So, 1 mole of MnO_4^- will need $\frac{2}{5}$ moles of FeC_2O_4

= 0.4 moles of MnO_4^-

25. (d) More negative the reduction potential, more will be its reducing power, so among these, Z being the most powerful reducing agent, Z > X > Y.

26. (b) Dissociation of sulfuric acid can be represented as:

$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$

Dissociation of water is:

$H_2O \rightarrow H^+ + OH^-$

At anode: $4OH^- \rightarrow 2H_2O + O_2 + 4e^-$

At Cathode: $2H^+ + 2e^- \rightarrow H_2$

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CHAPTER 8

The p-Block Elements

Group 13 Elements (Boron Family)

1. Taking stability as the factor, which one of the following represents correct relationship? [MR*] *(2023)*

a. $TlI > TlI_3$ b. $TlCl_3 > TlCl$
c. $InI_3 > InI$ d. $AlCl > AlCl_3$

2. Select the element (M) whose trihalides **cannot** be hydrolysed to produce an ion of the form $[M(H_2O)_6]^{3+}$ [MR*] *(2023-Manipur)*

a. Ga b. In
c. Al d. B

3. The correct order of atomic radii in group 13 elements is *(2018)*

a. B < Al < In < Ga < Tl b. B < Al < Ga < In < Tl
c. B < Ga < Al < In < Tl d. B < Ga < Al < Tl < In

4. Which one of the following elements is unable to form MF_6^{3-} ion? *(2018)*

a. Ga b. Al
c. In d. B

5. AlF_3 is soluble in HF only in presence of KF. It is due to the formation of: *(2016-II)*

a. $K_3[AlF_3H_3]$ b. $K_3[AlF_6]$
c. AlH_3 d. $K[AlF_3H_3]$

6. The stability of +1 oxidation state among Al, Ga, In and Tl increases in the sequence: *(2015 Re)*

a. In < Tl < Ga < Al b. Ga < In < Al < Tl
c. Al < Ga < In < Tl d. Tl < In < Ga < Al

7. The stability of +1 oxidation state increases in the sequence: *(2009)*

a. Tl < In < Ga < Al b. In < Tl < Ga < Al
c. Ga < In < Al < Tl d. Al < Ga < In < Tl

8. Which of the following compound is electron deficient? *(2000)*

a. $BeCl_2$ b. BCl_3
c. CCl_4 d. PCl_5

9. Boron compounds behave as Lewis acids, because of their: *(1996)*

a. Ionisation property b. Electron deficient nature
c. Acidic nature d. Covalent nature

10. Aluminium(III) chloride forms a dimer because aluminiu *(19*

a. Belongs to 3rd group
b. Can have higher coordination number
c. Cannot form a trimer
d. Has high ionization energy

Compounds of Boron, Uses of B & Al and Their Compounds

11. Match List - I with List - II: *(2022 I*

	List-I (Compounds)		List-II (Molecular formula
A.	Borax	I.	$NaBO_2$
B.	Kernite	II.	$Na_2B_4O_7 \cdot 4H_2O$
C.	Orthoboric acid	III.	H_3BO_3
D.	Borax bead	IV.	$Na_2B_4O_7 \cdot 10H_2O$

Choose the **correct answer** from the options given below

a. A-I, B-III, C-IV, D-II b. A-IV, B-II, C-III, D-I
c. A-II, B-IV, C-III, D-I d. A-III, B-I, C-IV, D-II

12. $Na_2B_4O_7 \xrightarrow{heat} X + NaBO_2$ *(2022 I*

In the above reaction the product "X" is :

a. NaB_3O_5 b. H_3BO_3
c. B_2O_3 d. $Na_2B_2O_5$

13. Which of the following statement is not correct ab diborane? [MR*] *(20*

a. Both the Boron atoms are sp^2 hyridised.
b. There are two 3-centre-2-electron bonds.
c. The four terminal B-H bonds are two centre two elect bonds
d. The four terminal Hydrogen atoms and the two Bo atoms lie in one plane.

14. Boric acid is an acid because its molecule: *(2016 -*

a. Accepts OH^- from water releasing proton
b. Combines with proton from water molecule
c. Contains replaceable H^+ ion
d. Gives up a proton

15. Which of the following is the electron deficient molecule? *(2005)*

a. B_2H_6 b. C_2H_6
c. PH_3 d. SiH_4

16. Which one of the following compounds is not a protonic acid? *(2003)*

a. $B(OH)_3$ b. $PO(OH)_3$
c. $SO(OH)_2$ d. $SO_2(OH)_2$

17. In borax bead test which compound is formed: *(2002)*

a. Ortho borate b. Meta borate
c. Double oxide d. Tetra borate

18. The type of hybridisation of boron in diborane is: *(1999)*

a. sp-hybridisation b. sp^2-hybridisation
c. sp^3-hybridisation d. sp^3d^2-hybridisation

19. Which of the following statements about H_3BO_3 is not correct? [MR*] *(1994)*

a. It has a layer structure in which planar BO_3 units are joined by hydrogen bonds.
b. It does not act as proton donor but acts as a Lewis acid by accepting hydroxyl ion.
c. It is a strong tribasic acid
d. It is prepared by acidifying an aqueous solution of borax

Group 14 Elements (Carbon Family)

20. Match the following : *(2020)*

Oxide		Nature	
A.	CO	(i)	Basic
B.	BaO	(ii)	Neutral
C.	Al_2O_3	(iii)	Acidic
D.	Cl_2O_7	(iv)	Amphoteric

Which of the following is correct option?

	(A)	(B)	(C)	(D)
a.	(ii)	(i)	(iv)	(iii)
b.	(iii)	(iv)	(i)	(ii)
c.	(iv)	(iii)	(ii)	(i)
d.	(i)	(ii)	(iii)	(iv)

21. Which of the following oxide is amphoteric in nature? *(2020-Covid)*

a. SiO_2 b. GeO_2
c. CO_2 d. SnO_2

22. Which of the following species is not stable? *(2019)*

a. $[SiF_6]^{2-}$ b. $[GeCl_6]^{2-}$
c. $[Sn(OH)_6]^{2-}$ d. $[SiCl_6]^{2-}$

23. Which of the following is incorrect statement? [MR*] *(2019)*

a. PbF_4 is covalent in nature
b. $SiCl_4$ is easily hydrolysed
c. GeX_4 (X = F, Cl, Br, I) is more stable than GeX_2
d. SnF_4 is ionic in nature

24. It is because of inability of ns^2 electrons of the valence shell to participate in bonding that: *(2017-Delhi)*

a. Sn^{4+} is reducing while Pb^{4+} is oxidising
b. Sn^{2+} is reducing while Pb^{4+} is oxidising
c. Sn^{2+} is oxidising while Pb^{4+} is reducing
d. Sn^{2+} and Pb^{2+} are both oxidising and reducing

25. Which of the following statements is incorrect? *(2011 Mains)*

a. Pure sodium metal dissolves in liquid ammonia to give blue solution
b. NaOH reacts with glass to give sodium silicate
c. Aluminium reacts with excess NaOH to give $Al(OH)_3$
d. $NaHCO_3$ on heating gives Na_2CO_3

26. Which of the following oxide is amphoteric? *(2011 Mains)*

a. SiO_2 b. CO_2
c. SnO_2 d. CaO

27. Which of the following oxidation states are the most characteristic for lead and tin respectively? *(2007)*

a. +2, +4 b. +4, +4
c. +2, +2 d. +4, +2

28. Carbon and silicon belong to (IV) group. The maximum coordination number of carbon in commonly occurring compounds is 4, whereas that of silicon is 6. This is due to: *(1994)*

a. Availability of low lying *d*-orbitals in silicon
b. Large size of silicon
c. More electropositive nature of silicon
d. Both (b) and (c)

Allotropes of Carbon

29. Match List-I with List-II *(2023)*

List-I		List-II	
A.	Coke	I.	Carbon atoms are sp^3 hybridised.
B.	Diamond	II.	Used as a dry lubricant
C.	Fullerene	III.	Used as a reducing agent
D.	Graphite	IV.	Cage like molecules

Choose the correct answer from the options given below:

a. A-III, B-IV, C-I, D-II b. A-II, B-IV, C-I, D-III
c. A-IV, B-I, C-II, D-III d. A-III, B-I, C-IV, D-II

30. Choose the correct statement: [MR*] *(2022)*

a. Both diamond and graphite are used as dry lubricants.
b. Diamond and graphite have two dimensional network
c. Diamond is covalent and graphite is ionic
d. Diamond is sp^3 hyridised and graphite is sp^2 hybridized.

31. Which of the following structure is similar to graphite? *(2013)*

a. BN b. B
c. B_4C d. B_2H_6

32. Which of the following does not show electrical conduction? *(1999)*

a. Potassium b. Graphite
c. Diamond d. Sodium

33. Percentage of lead in lead pencil: *(1999)*

a. Zero b. 20
c. 80 d. 70

34. In graphite, electrons are: *(1997, 1993)*

a. Localised on each C-atom
b. Localised on every third C-atom
c. Spread out between the structure
d. Present in anti-bonding orbital

35. Which of the following types of forces bind together the carbon atoms in diamond? *(1992)*

a. Ionic b. Covalent
c. Dipolar d. Van der Waals

36. Which of the following is an insulator? *(1992)*

a. Graphite b. Aluminum
c. Diamond d. Silicon

37. The ability of a substance to assume two or more crystalline structures is called: *(1990)*

a. Isomerism b. Polymorphism
c. Isomorphism d. Amorphism

Some Important Compounds of C & Si

38. Identify the correct statements from the following: *(2020)*

(1) $CO_2(g)$ is used as refrigerant for ice-cream and frozen food.
(2) The structure of C_{60} contains twelve six carbon rings and twenty five carbon rings.
(3) ZSM-5, a type of zeolite, is used to convert alcohols into gasoline.
(4) CO is colorless and odourless gas.

a. (1) and (3) only b. (2) and (3) only
c. (3) and (4) only d. (1), (2) and (3) only

39. Which of the following is not correct about carbon monoxide? *(2020)*

a. It reduces oxygen carrying ability of blood.
b. The carboxyhaemoglobin (haemoglobin bound to CO) is less stable than oxyhaemoglobin.
c. It is produced due to incomplete combustion.
d. It forms carboxyhaemoglobin.

40. Which of these is not a monomer for a high molecular mass silicone polymer? *(2013)*

a. $MeSiCl_3$ b. Me_2SiCl_2
c. Me_3SiCl d. $PhSiCl_3$

41. The basic structural unit of silicates is: *(2013)*

a. SiO^- b. SiO_4^{4-}
c. SiO_3^{2-} d. SiO_4^{2-}

42. Name the type of the structure of silicate in which one oxygen atom of $[SiO_4]^{4-}$ is shared: **[MR*]** *(2011 Prel)*

a. Three dimensional b. Linear chain silicate
c. Sheet silicate d. Pyrosilicate

43. The straight chain polymer is formed by: *(2009)*

a. Hydrolysis of CH_3SiCl_3 followed by condensation polymerisation
b. Hydrolysis of $(CH_3)_4$ Si by addition polymerisation
c. Hydrolysis of $(CH_3)_2SiCl_2$ followed by condensation polymerisation
d. Hydrolysis of $(CH_3)_3SiCl$ followed by condensation polymerisation

44. Which of the following anions is present in the chain structure of silicates? *(2007)*

a. $(Si_2O_5^{2-})_n$ b. $(SiO_3^{2-})_n$
c. SiO_4^{4-} d. $Si_2O_7^{6-}$

45. Which one of the following statements about the zeolites is false? **[MR*]** *(2004)*

a. They have open structure which enables them to take up small molecules
b. Zeolites are aluminosilicates having three dimensional network
c. Some of the SiO_4^{4-} units are replaced by AlO_4^{5-} and AlO_6^{7-} ions in zeolites
d. They are used as cation exchangers

46. Water gas is produced by: *(1992)*

a. Passing steam through a red hot coke bed
b. Saturating hydrogen with moisture
c. Mixing oxygen and hydrogen in the ratio of 1 : 2
d. Heating a mixture of CO_2 and CH_4 in petroleum refineries

47. The substance used as a smoke screen in warfare is: *(1989)*

a. $SiCl_4$ b. PH_3
c. PCl_5 d. Acetylene

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Answer Key

1. (a)	2. (d)	3. (c)	4. (d)	5. (b)	6. (c)	7. (d)	8. (b)	9. (b)	10. (b)
11. (b)	12. (c)	13. (a)	14. (a)	15. (a)	16. (a)	17. (b)	18. (c)	19. (c)	20. (a)
21. (d)	22. (d)	23. (a)	24. (b)	25. (c)	26. (c)	27. (a)	28. (a)	29. (d)	30. (d)
31. (a)	32. (c)	33. (a)	34. (c)	35. (b)	36. (c)	37. (b)	38. (c)	39. (b)	40. (c)
41. (b)	42. (d)	43. (c)	44. (b)	45. (c)	46. (a)	47. (a)			

Explanations

1. (a) Tl^{+3} is less stable than Tl^{+1} (inert pair effect)

Going down the group 13, stability of lower oxidation state increases.

In case of B, Al, Ga and In, higher O.S. +3 remains more stable than lower O.S. +1.

But, in last stable element, thallium (Tl), lower O.S. +1 become more stable than higher O.S. +3.

2. (d) The maximum covalency of boron four due to which its halide cannot be hydrolysed.

3. (c) Generally, on moving down the group, ionic or atomic radii increases due to the addition of a new shell. But in Group 13, the correct order for the atomic radii of the elements is B < Ga < Al < In < Tl.

It can be seen that atomic radius of Ga is slightly lower than that of Al. This is due to the presence of d-electrons in Ga which do not shield the nucleus effectively. As a result, the electrons in Ga experience greater force of attraction by the nucleus than in Al, and hence the atomic radius of Ga is slightly less than that of Al.

4. (d) ∵ 'B' has no vacant d-orbitals in its valence shell, so it can't extend its covalency beyond 4, i.e., 'B' cannot form the ion like MF_6^{3-} i.e. BF_6^{3-}.
Hence, the correct option is (d).

5. (b) Aluminum forms fluoride complexes more easily. So, AlF_3 easily dissolves in a mixture of (HF + KF). AlF_3 is soluble in HF in the presence of KF due to formation of soluble complex $K_3[AlF_6]$. The reaction takes place as:

$$AlF_3 + 3KF \xrightarrow{HF} K_3[AlF_6]$$

AlF_3 is insoluble in anhydrous HF because $F^{\ominus}$ ion are not available in hydrogen bonded, HF.

6. (c) The stability of +1 oxidation state among Al, Ga, In and Tl increases in the following order : Al < Ga < In < Tl.
This is due to inert pair effect, according to which, on moving down the group, the stability of +3 oxidation state decreases while that of +1 oxidation state increases.

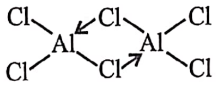
7. (d) The correct order is : Al < Ga < In < Tl.

This is due to inert pair effect, according to which, on moving down the group, the stability of +3 oxidation state decreases while that of +1 oxidation state increases.

8. (b) In BCl_3 the central atom 'B' is sp^2 hybridised and contains only 'Six' electrons in its valence shell. Therefore it is electron deficient.

9. (b) Lewis acids are those substances which can accept a pair of electrons. Since boron compounds are deficient in electrons, therefore, they behave as Lewis acids.

10. (b) $AlCl_3$ forms a dimer as it enables Al atoms to complete their octets which helps aluminum to acquire higher coordination number.

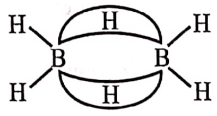


11. (b)

(Compounds)		(Molecular formula)
Borax	→	$Na_2B_4O_7.10H_2O$
Kernite	→	$Na_2B_4O_7.4H_2O$
Orthoboric acid	→	H_3BO_3
Borax bead	→	$NaBO_2$

12. (c) $\underset{\text{(Borax)}}{Na_2B_4O_7} \xrightarrow{\text{heat}} \underset{\text{(Boric anhydride)}}{B_2O_3} + \underset{\text{(Sodium metaborate)}}{2NaBO_2}$

13. (a)



B_2H_6

B is sp^3 hybridized.

3 centre 2 electron bond which is called bridge bonding or banana bond.

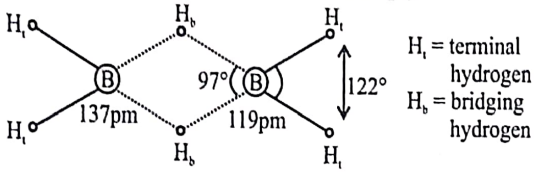
There are two different bonds that is 3 centre 2 electron and 2 centre 2 electron. So bond lengths are different.

Molecule is non-planar as 4 terminal hydrogen atoms and two boron atoms lie in one plane and rest two hydrogen lies in another plane.

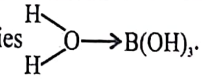
14. (a) Boric acid is an electron deficient compound, therefore, acts as a Lewis acid. Lewis acids are those substances which can accept a pair of electrons. Thus, boric acids accepts hydroxyl ions ($OH^{\ominus}$) in aqueous solution to compete its octet because it is an electron deficient compound.
The reaction takes place as:

$$B(OH)_3 + H_2O \rightleftharpoons [B(OH)_4]^{\ominus} H^{\oplus}$$

15. **(a)** B_2H_6 (diborane) is an electron deficient molecule. It forms banana bond but 2 orbitals remains empty.

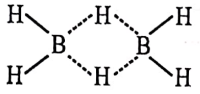


Structure of diborane

16. **(a)** $B(OH)_3$ in aqueous medium coordinates a molecule & water to form hydrates species  $\longrightarrow B(OH)_3$. In this species, B^{3+} ions, because of its small size, exercise a high polarizing power thereby pulling the sigma electron charge of the coordinated 'O' atom towards itself. The coordinated oxygen in turn pulls the sigma electron charge of the OH bond of the attached water molecule toward itself.

17. **(b)** In borax bead test, the compound formed is metaborate.

18. **(c)** Each boron atom in diborane is sp^3 hybridised



19. **(c)** H_3BO_3 is a weak monobasic acid. We know that, $B(OH)_3 + H_2O \rightarrow [B(OH)_4]^- + H^+$. Since it does not act as proton donor but acts as Lewis acid by accepting hydroxyl ions, therefore, it is a weak monobasic acid.

20. **(a)** Generally, metal oxides are basic in nature, while non-metal oxides are acidic in nature.

Since BaO is metal oxide, as Ba is a metal, therefore it is basic. On the other hand, Cl_2O_7 is a non-metallic oxide, therefore, acidic in nature.

Neutral oxides are oxides which are neither acidic nor basic. CO is neutral oxide.

Amphoteric oxides react with both acids and alkalis to form salt and water. Al_2O_3 is an amphoteric oxide.

21. **(d)** Ampheteric oxides are those oxides which react with both acids and bases.

Among the given oxides, only SnO_2 can react with both acids and bases, hence amphoteric in nature.

CO_2, SiO_2 and GeO_2 are acidic in nature.

22. **(d)**

- Due to presence of vacant d-orbital in Si, Ge and Sn they form species like SiF_6^{2-}, $[GeCl_6]^2$, $[Sn(OH)_6]^{2-}$
- $SiCl_6^{2-}$ does not exist because six large chloride ions cannot be accommodated around Si^{4+} due to its small size.
- Also, interaction between lone pair of chloride ion and Si^{4+} is not very strong.

23. **(a)**

(a) According to Fajan's rule, the smaller the size of the cation and the larger the six of the anion, the greater the covalent character of an ionic bond. Since in PbF_4, the cation Pb^{4+} is bigger and anion $F^{\ominus}$ is smaller, therefore, PbF_4 is ionic in nature.

(b) $SiCl_4$ is easily hydrolysed because it has unoccupie 3d orbital that are able to accept electron pairs from th oxygen atoms on water to form bond.

$SiCl_4 + 3H_2O \longrightarrow H_2SiO_3 + 4HCl$

(c) GeX_4 is more stable than GeX_2 as in GeX_4 Ge is in + oxidation state. And +4 oxidation state of Ge is mo stable than +2 in GeX_2 due to inert pair effect.

(d) SnF_4 is ionic in nature as $F^{\ominus}$ ion is very small and Sn^{4+} io is very large. So, it is ionic in nature according to Fajan rule.

24. **(b)** As we go down the group, the outermost 's' electron of the ns^2np^2 configuration tends not to participate in bon formation. Hence, the stability of maximum oxidation stat decreases and the stability of (max. –2) oxidation stat increases. This is called inert pair effect. This implies tha Pb^{4+} would want to grab two electrons and become the mor stable Pb^{2+} and itself get reduced. Hence, Pb^{4+} is oxidising Likewise, for tin, Sn^{4+} is more stable than Sn^{2+}, and hence Sn^{2+} would like to lose two electrons and become the mor stable Sn^{4+}. Thus, Sn^{2+} is reducing.

25. **(c)** The aluminum reacts with the sodium hydroxide an forms a sodium aluminate. The reaction between th aluminum and sodium hydroxide can be written as:

$2Al + 2NaOH + 2H_2O \longrightarrow 2NaAlO_2 + 3H_2$.

Thus, unlike other, aluminum do not form aluminum hydroxide, $Al(OH)_3$, when treated with sodium hydroxide.

26. **(c)** Tin (Sn) forms amphoteric oxide, that is can react wit both acids and bases.

27. **(a)** All group IV elements show tetravalency, which can b explained on the basis of shifting of one electron from *n* orbital to the vacant *np* orbital. These four orbitals give ris to four sp^3 hybrid orbitals.

When ns^2 electrons of outermost shell do not participate i bonding, it is called inert pair. The last three elements of grou 4, which are Ge, Sn and Pb, have a tendency to form divalent a well as tetravalent ions. Since the inert pair effect increases fron Ge to Pb, the stability of tetravalent ion decreases and that o divalent ion increases. That is why, Pb^{2+} is more stable than Pb^{4+} and Sn^{4+} ions are more stable than Sn^{2+}.

28. **(a)** Carbon has no *d*-orbitals, while silicon contains *d*-orbital which can be used for bonding purposes.

29. **(d)** Coke- reducing agent

Diamond- sp^3 carbons

Fullerenes- cage like structure

Graphite- used as lubricant

30. **(d)** Only graphite is used as a lubricant. Both diamond an graphite are covalent in nature.

In diamond each carbon is bonded with four other carbon atoms. So hybridisation of carbon atom is sp^3.

In graphite each carbon is bonded with three other carbon atoms. So hybridisation of carbon atom is sp^2.

31. (a) Both graphite and BN have similar structures. Graphite has layered structure. Layers are held by Vander Waals forces and each layer is composed of planar hexagonal rings of carbon atoms. Each C-atom in hexagonal ring undergoes sp^2 hybridisation and makes three sigma bonds with three neighbouring carbon atoms.

In the similar way, BN consists of flat planes of hexagons. Each hexagon having alternate B and N atoms with the difference that, in graphite each corner of the hexagon has C-atom.

32. (c) Diamond is an insulator due to absence of free electrons

33. (a) In lead, pencil graphite and clay is present so the percent of lead is zero

34. (c) In graphite, each carbon atom undergoes sp^2 - hybridisation and is covalently bonded to three other carbon atoms by single bonds. The fourth electron in each carbon atom become delocalised over the whole of the sheet.

35. (b) In diamond, each carbon atom is sp^3 hybridised and thus forms covalent bonds with four other carbon atoms lying at the corners of a regular tetrahedron.

36. (c) All the above are conductors except diamond. Hence diamond is an insulator as it does not contains any free e^{-1}s for conduction.

37. (b) The phenomenon of existence of a substance in two or more crystalline structures is called polymorphism. Polymorphism of elements is known as allotropy.

38. (c)

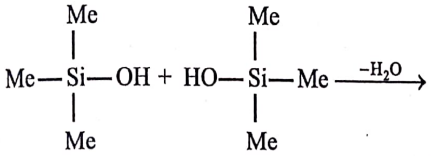
(1) Dry ice, $CO_2(s)$, is used as refrigerant not $CO_2(g)$.

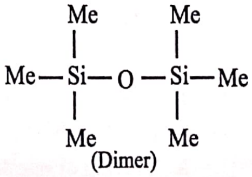
(2) C_{60} contains 20 six membered rings, 12 five membered rings

Statement 3 and 4 are correct.

39. (b) Carbon monoxide binds with Hb to form carboxyhaemoglobin which is 300 times more stable compound than oxyhaemoglobin complex.

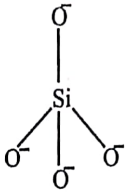
40. (c) Me_3SiCl is not a monomer for high molecular mass silicone polymer because it generates Me_3SiOH when subjected to hydrolysis which contains only one reacting site. Hence, the polymerisation stops just after first step.



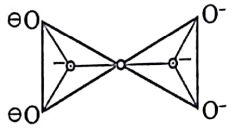


(Dimer)

41. (b) Basic unit for silicates is SiO_4^{4-}

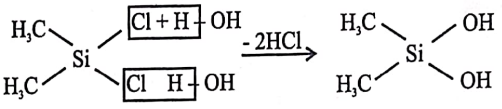


42. (d) In pyrosilicates, only one oxygen atom is shared as shown below:



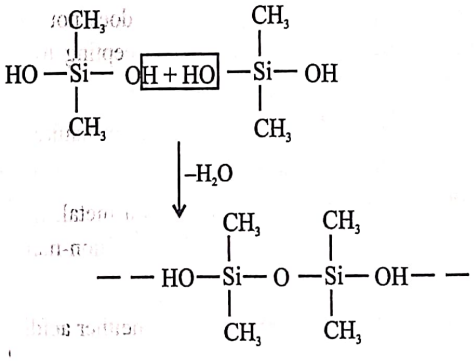
Pyrosilicate

43. (c) $(CH_3)_2SiCl_2$ will give linear polymer on hydrolysis followed by polymerisation.



Dimethyl dichlorosilane

Dimethyl silanol



44. (b) In SiO_3^{2-}, two oxygen atoms per SiO_4 tetrahedron are shared giving polymeric anion chains.

E.g. : Spodumene $LiAl(SiO_3)_2$, Diposide $CaMg(SiO_3)_2$.

45. (c) Zeolite have SiO_4 and AlO_4 tetrahedrons, linked together in a three dimensional open structure in which 4 or 6 membered rings predominate. Due to open chain structure they have cavities and can take up water and other small molecules

46. (a) $H_2O + C \xrightarrow[\text{Red hot}]{\text{Steam}} \underbrace{H_2 + CO}_{\text{water gas}}$

47. (a) $SiCl_4$ gets hydrolysed in moist air and gives white fumes which are used as a smoke screen in warfare.

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CHAPTER 9

Organic Chemistry-Some Basic Principles and Techniques

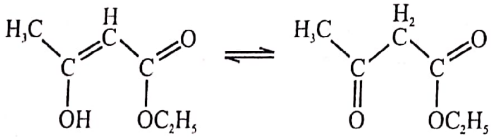
Tetravalence of Carbon (Shapes of Organic Compounds)

1. The number of σ bonds, π bonds and lone pair of electrons in pyridine, respectively are *(2023)*
   a. 12, 2, 1 b. 11, 2, 0
   c. 12, 3, 0 d. 11, 3, 1

2. Which of the following molecules represents the order of hybridisation sp^2, sp^2, sp, sp from left to right atoms? *(2018)*
   a. $HC \equiv C - C \equiv CH$ b. $CH_2 = CH - C \equiv CH$
   c. $CH_3 - CH = CH - CH_3$ d. $CH_2 = CH - CH = CH_2$

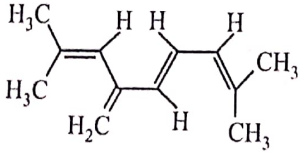
3. Which of the following species contains equal number of σ-bonds and π-bonds? [MR*] *(2015)*
   a. $(CN)_2$ b. $CH_2(CN)_2$
   c. HCO_3^- d. XeO_4

4. The enolic form of ethyl acetoacetate as shown below has *(2015)*



   a. 9 σ-bonds and 2 π-bonds
   b. 9 σ-bonds and 1 π-bonds
   c. 18 σ-bonds and 2 π-bonds
   d. 16 σ-bonds and 1 π-bond

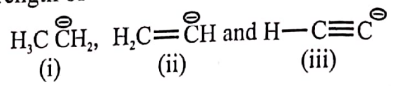
5. The total number of π-bond electrons in the following structure is [MR*] *(2015)*



   a. 12 b. 16
   c. 4 d. 8

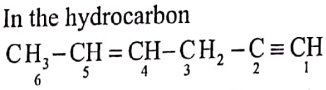
6. Considering the state hybridisation of carbon atoms, find out the molecule among the following which is linear? *(2011)*
   a. $CH_3 - CH = CH - CH_3$
   b. $CH_3 - C \equiv C - CH_3$
   c. $CH_2 = CH - CH_2 - C \equiv CH$
   d. $CH_3 - CH_2 - CH_2 - CH_3$

7. Base strength of



   is in the order of: [MR*] *(2008)*
   a. (i) > (iii) > (ii) b. (i) > (ii) > (iii)
   c. (ii) > (i) > (iii) d. (iii) > (ii) > (i)

8. In the hydrocarbon



   The state of hybridisation of carbons 1, 3 and 5 are in the following sequence: *(2008)*
   a. sp^3, sp^2, sp b. sp^2, sp, sp^3
   c. sp, sp^3, sp^2 d. sp, sp, sp^3

9. In which of the following compound there is more than one kind of hybridisation (*sp*, sp^2, sp^3) for carbon? *(1995)*
   a. $CH_2 = CH - CH = CH_2$
   b. $H - C \equiv C - H$
   c. $CH_3CH_2CH_2CH_3$
   d. $CH_3 - CH = CH - CH_3$

10. Which of the following statement is not correct? *(1993)*
    a. Double bond is shorter than a single bond
    b. Sigma bond is weaker than a π (pi) bond
    c. Double bond is stronger than a single bond
    d. Covalent bond is stronger than hydrogen bond

11. When the hybridisation state of carbon atom changes from sp^3 to sp^2 and finally to *sp*, the angle between the hybridised orbitals: *(1993)*
    a. Decreases gradually b. Decreases considerably
    c. Is not affected d. Increases progressively

12. The restricted rotation about carbon carbon double bond in 2-butene is due to: *(1993)*
    a. Overlap of one *s* and sp^2-hybridised orbitals
    b. Overlap of two sp^2-hybridised orbitals
    c. Overlap of one *p* and one sp^2-hybridised orbitals
    d. Sideways overlap of two *p*-orbitals

13. The shortest C–C bond distance is found in: *(1991)*
    a. Diamond b. Ethane
    c. Benzene d. Acetylene

14. A sp^3 hybrid orbital contains: *(1991)*
    a. 1/4 *s*-character b. 1/2 *s*-character
    c. 1/3 s-character d. 2/3 *s*-character

15. A straight chain hydrocarbon, has the molecular formula C_8H_{10}. The hybridisation of the carbon atoms from one end of the chain to the other are respectively sp^3, sp^2, sp^2, sp^3, sp^2, sp^2, sp, and sp. The structural formula of the hydrocarbon would be: [MR*] *(1991)*

a. $CH_3C \equiv CCH_2 - CH = CHCH = CH_2$
b. $CH_3CH_2 - CH = CHCH = CHC \equiv CH$
c. $CH_3CH = CHCH_2 - C \equiv CCH = CH_2$
d. $CH_3CH = CHCH_2 - CH = CHC \equiv CH$

16. Which of the following possesses a sp-carbon in its structure? *(1989)*

a. $CH_2 = CCl - CH = CH_2$ b. $CCl_2 = CCl_2$
c. $CH_2 = C = CH_2$ d. $CH_2 = CH - CH = CH_2$

17. The Cl – C – Cl angle in 1, 1, 2, 2-tetrachloroethene and tetrachloromethane respectively will be about: *(1988)*

a. 120^0 and 109.5^0 b. 90^0 and 109.5^0
c. 109.5^0 and 90^0 d. 109.5^0 and 120^0

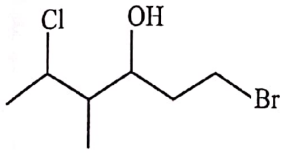
Classification, Nomenclature of Organic Compounds

18. What is the hybridization shown by C_1 and C_2 carbons, respectively in the given compound? [MR*] *(2022 Re)*

$$OHC - CH = CH - CH_2COOCH_3$$

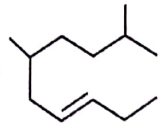
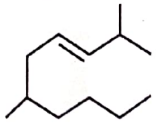
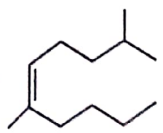
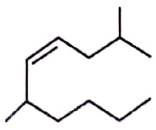
a. sp^3 and sp^3 b. sp^2 and sp^3
c. sp^2 and sp^2 d. sp^3 and sp^2

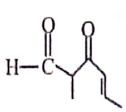
19. The correct IUPAC name of the following compound is: *(2022)*



a. 6-bromo-4-methyl-2-chlorohexan-4-ol
b. 1-bromo-5-chloro-4-methylhexan-3-ol
c. 6-bromo-2-chloro-4-methylhexan-4-ol
d. 1-bromo-4-methyl-5-chlorohexan-3-ol

20. The correct structure of 2,6-Dimethyl-dec-4-ene is: *(2021)*

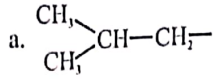
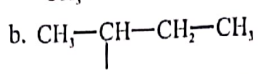
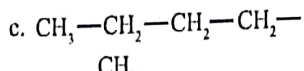
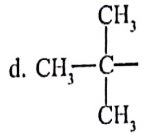
a. 
b. 
c. 
d. 

21. The IUPAC name of the compound  is

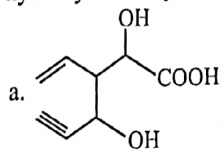
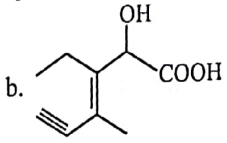
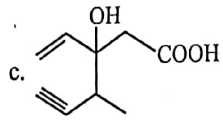
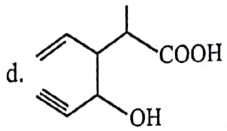
(2017-Delhi)

a. 3–keto–2–methylhex–5–enal
b. 3–keto–2–methylhex–4–enal
c. 5–formylhex–2–en–3–one
d. 5–methyl–4–oxohex–2–en–5–al

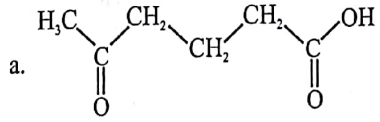
22. The structure of isobutyl group in an organic compound is: *(2013)*

a. 
b. 
c. 
d. 

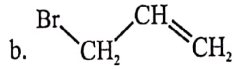
23. Structure of the compound whose IUPAC name is 3-Ethyl-2-hydroxy-4-methylhex-3-en-5-ynoic acid is: [MR*] *(2013)*

a. 
b. 
c. 
d. 

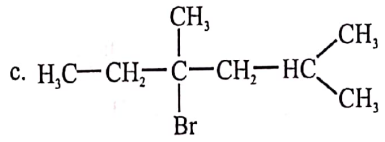
24. Which nomenclature is not according to IUPAC system? [MR*] *(2012 Pre)*

a. 

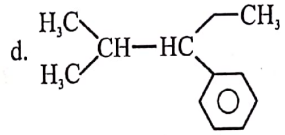
5- oxohexanoic acid

b. 

3-Bromo-prop-2-ene

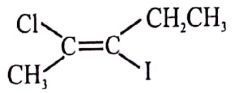
c. 

4-bromo-2,4-dimethylhexane

d. 

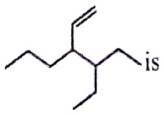
2-Methyl-3-phenyl pentane

25. The IUPAC name of the following compound is: *(2011 Mains)*



a. trans-3-iodo-4-chloro-3-pentene
b. cis-3-chloro-3-iodo-2-pentene
c. trans-2-chloro-3-iodo-2-pentene
d. cis-3-iodo-4-chloro-3-pentene

26. The correct IUPAC name of the compound is: *(2011 Pre)*


is

a. 3-(1-ethyl propyl) hex-1-ene
b. 4-Ethyl-3-propyl hex-1-ene
c. 3-Ethyl-4-ethenyl heptane
d. 3-Ethyl-4-propyl hex-5-ene

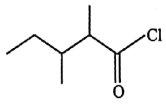
The IUPAC name of the compound $CH_3CH{=}CHC{\equiv}CH$ is: *(2010 Mains)*

a. Pent-4-yn-2-ene b. Pent-3-en-1-yne
c. Pent-2-en-4-yne d. Pent-1-yn-3-ene

28. The IUPAC name of the compound having the formula $CH \equiv C - CH = CH_2$ is: [MR*] *(2009)*

a. 1-butyn-3-ene b. but-1-yne-3-ene
c. 1-butene-3-yne d. 3-butene-1-yne

29. The IUPAC name of



is: *(2006)*

a. 3, 4-dimethylpentanoyl chloride
b. 1-chloro-1-oxo-2, 3-dimethylpentane
c. 2-ethyl-3-methylbutanoyl chloride
d. 2, 3-dimethylpentanoyl chloride

30. Names of some compounds are given. Which one is not correct in IUPAC system? *(2005)*

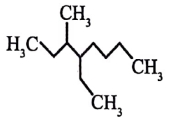
a. $CH_3-\underset{\underset{OH}{|}}{CH}-\underset{\underset{CH_3}{|}}{CH}-CH_3$
3-methyl-2 butanol

b. $CH_3 - C \equiv C - CH(CH_3)_2$
4-methyl-2-pentyne

c. $CH_3-CH_2-\underset{\underset{CH_2}{||}}{C}-\underset{\underset{CH_3}{|}}{CH}-CH_3$
2-ethyl-3 methyl-but-1-ene

d. $CH_3-CH_2-CH_2-\underset{\underset{CH_2CH_3}{|}}{CH}-\underset{\underset{CH_3}{|}}{CH}-CH_2CH_3$
3-methyl-4 ethyl heptane

31. Name of the compound given below is: *(2003)*



a. 4-ethyl-3-methyloctane b. 3-methyl-4-ethyloctane
c. 2, 3-diethylheptane d. 5-ethyl-6-methyloctane

32. IUPAC name of the following is: *(2002)*

$CH_2 = CH - CH_2 - CH_2 - C \equiv CH$

a. 1, 5-hexenyne b. 1-hexene-5-yne
c. 1-hexyne-5-ene d. 1, 5-hexynene

33. The incorrect IUPAC name is: *(2001)*

a. $-CH_3-\underset{\underset{O}{||}}{C}-\underset{\underset{CH_3}{|}}{CH}-CH_3$ 2-methyl-3-butanone

b. $CH_3-\underset{\underset{CH_3}{|}}{CH}-\underset{\underset{CH_2-CH_3}{|}}{CH}-CH_3$ 2, 3-dimethyl pentane

c. $CH_3 - C \equiv CCH(CH_3)_2$ 4-methyl-2-pentyne

d. $CH_3-\underset{\underset{Cl}{|}}{CH}-\underset{\underset{Br}{|}}{CH}-CH_3$ 2-bromo-3-chloro butane

34. The IUPAC name of $(CH_3)_2CH - CH_2 - CH_2Br$ is: *(1996)*

a. 1-bromo-3-methylbutane b. 2-methyl-3-bromopropane
c. 1-bromopentane d. 2-methyl-4-bromobutane

35. The IUPAC name for

$CH_3CH = CHCH_2\underset{\underset{NH_2}{|}}{CH}CH_2COOH$ is: *(1995)*

a. 3-amino-5-heptenoic acid
b. β-amino-δ-heptenoic acid
c. 5-amino-2-heptenoic acid
d. 5-amino-hex-2-enecarboxylic acid

36. The IUPAC name of: *(1992)*

$CH_3-\underset{\underset{OH}{|}}{CH}-CH=\underset{\underset{CH_3}{|}}{C}-CHO$

a. 4-hydroxy-1-methylpentanal
b. 4-hydroxy-2-methylpent-2-en-1-al
c. 2-hydroxy-4-methylpent-3-en-5-al
d. 2-hydroxy-3-methylpent-2-en-5-al

37. 2-Methyl-2-butene will be represented as: *(1992)*

a. $CH_3-\underset{\underset{H_3C}{|}}{CH}=CH_2\ CH_3$ b. $CH_3-\underset{\underset{CH_3}{|}}{C}=CHCH_3$

c. $CH_3-CH_2-\underset{\underset{CH_3}{|}}{C}=CH_3$ d. $CH_3-\underset{\underset{CH_3}{|}}{CH}-C=CH_2$

38. An organic compound X(molecular formula $C_6H_7O_2N$) has six carbon atoms in a ring system, two double bonds and a nitro group as substituent, X is: [MR*] *(1990)*

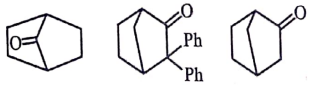
a. Homocyclic but not aromatic
b. Aromatic but not homocyclic
c. Homocyclic and aromatic
d. Heterocyclic and aromatic

Isomerism

39. The compound which shows metamerism is: *(2021)*

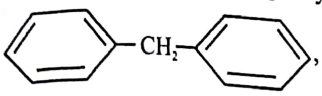
a. C_3H_8O b. C_3H_6O
c. $C_4H_{10}O$ d. C_5H_{12}

40. Which among the given molecules can exhibit tautomerism? [MR*] *(2016 - II)*



I II III

a. III only b. Both I and III
c. Both I and II d. Both II and III

41. The molecular formula of diphenyl methane,  , is $C_{13}H_{12}$.

How many structural isomers are possible when one of the hydrogens is replaced by a chlorine atom? [MR*] *(2004)*

a. 4 b. 8
c. 7 d. 6

42. Geometrical isomers are different in: *(2002)*

a. Position of functional group
b. Position of atoms
c. Spatial arrangement of atoms
d. Length of carbon chain

43. Tautomerism is exhibited by: *(1997)*

a. R_3CNO_2 b. RCH_2NO_2
c. $(CH_3)_3CNO$ d. $(CH_3)_2NH$.

44. The number of isomers in $C_4H_{10}O$ will be: [MR*] *(1996)*

a. 7 b. 8
c. 5 d. 6

45. Isomers of a substance must have the same: *(1991)*

a. Structural formula b. Physical properties
c. Chemical properties d. Molecular formula

46. Which one of the following can exhibit *cis-trans* isomerism? *(1989)*

a. $CH_3-CHCl-COOH$ b. $H-C\equiv C-Cl$
c. $ClCH=CHCl$ d. $ClCH_2-CH_2Cl$

47. How many chain isomers could be obtained from the alkane C_6H_{14}? *(1988)*

a. Four b. Five
c. Six d. Seven

Fundamental Concepts of Organic Reactions

48. Given below are **two** statements: *(2023-Manipur)*

Statement-I: In a organic compound, when inductive and electromeric effects operate in opposite directions, the inductive effect predominates.

Statement-II: Hyperconjugation is observed in o-xylene.

In the light of the above statements, choose the **correct** answer from the options given below:

a. **Statement-I** is true but **Statement-II** is false.
b. **Statement-I** is false but **Statement-II** is true.
c. Both **Statement-I** and **Statement-II** are true.
d. Both **Statement-I** and **Statement-II** are false.

49. Given below are two statements: one is labelled as Assertion **(A)** and the other is labelled as Reason **(R)**. [MR*] *(2022 Re)*

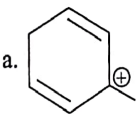
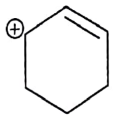
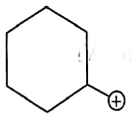
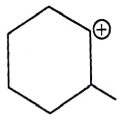
Assertion (A): Chlorine is an electron withdrawing group but it is ortho, para directing in electrophilic aromatic substitution.

Reason (R): Inductive effect of chlorine destabilises the intermediate carbocation formed during the electrophilic substitution, however due to the more pronounced resonance effect, the halogen stabilises the carbocation at ortho and para positions.

In the light of the above statements, choose the most appropriate answer from the options given below :

a. (A) is not correct but (R) is correct.
b. Both (A) and (R) are correct and (R) is the correct explanation of (A).
c. Both (A) and (R) are correct but (R) is not the correct explanation of (A).
d. (A) is correct but (R) is not correct.

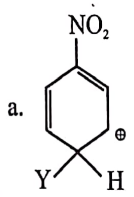
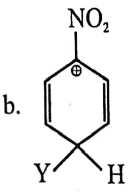
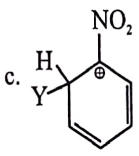
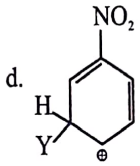
50. Which of the following is the most stable carbocation? *(2022 Re)*

a. 
b. 
c. 
d. 

51. A tertiary butyl carbocation is more stable than a secondary butyl carbocation because of which of the following? *(2020)*

a. + R effect of $-CH_3$ groups
b. – R effect of $-CH_3$ groups
c. Hyperconjugation
d. –I effect of $-CH_3$ groups

52. Which of the following carbocations is expected to be most stable? [MR*] *(2018)*

a. 
b. 
c. 
d. 

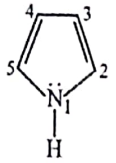
53. Which of the following is correct with respect to – I effect of the substituents? (R = alkyl) *(2018)*

a. $-NH_2 < -OR < -F$ b. $-NR_2 < -OR < -F$
c. $-NR_2 > -OR > -F$ d. $-NH_2 > -OR > -F$

54. The correct statement regarding electrophile is: *(2017-Delhi)*

a. Electrophile can be either neutral or positively charged species and can form a bond by accepting a pair of electrons from a nucleophile
b. Electrophile is a negatively charged species and can form a bond by accepting a pair of electrons from a nucleophile
c. Electrophile is a negatively charged species and can form a bond by accepting a pair of electrons from another electrophile
d. Electrophiles are generally neutral species and can form a bond by accepting a pair of electrons from a nucleophile

55. In pyrole, the electron density is maximum on [MR*] *(2016 - II)*

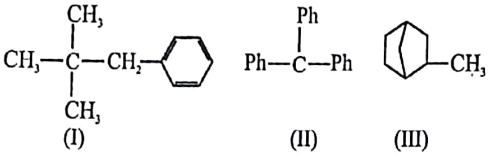


a. 2 and 3 b. 3 and 4
c. 2 and 4 d. 2 and 5

56. Which of the following statements is not correct for a nucleophile? *(2015 Re)*

a. Nucleophiles are not electron seeking
b. Nucleophile is a Lewis acid
c. Ammonia is a nucleophile
d. Nucleophiles attack low electron density sites

57. Consider the following compounds

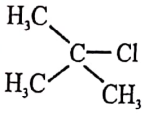


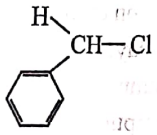
(I) (II) (III)

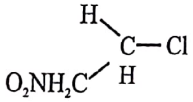
Hyperconjugation occurs in: *(2015)*

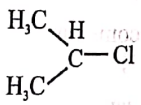
a. II only b. III only
c. I and III d. I only

58. In which of the following compounds, the C – Cl bond ionization shall give most stable carbonium ion? *(2015)*

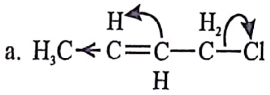
a. 

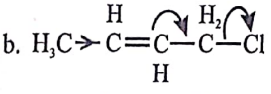
b. 

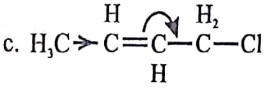
c. 

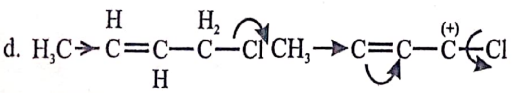
d. 

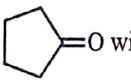
59. Which of the following is the most correct electron displacement for a nucleophilic reaction to take place? *(2015)*

a. 

b. 

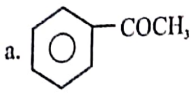
c. 

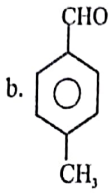
d. 

60. Treatment of cyclopentanone  with methyl lithium gives which of the following species? *(2015)*

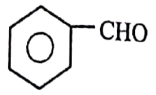
a. Cyclopentanonyl radical
b. Cyclopentanonyl biradical
c. Cyclopentanonyl anion
d. Cyclopentanonyl cation

61. Which one is most reactive towards nucleophilic addition reaction? [MR*] *(2014)*

a. 

b. 

c.

d. 

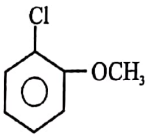
62. Some *meta*-directing substituents in aromatic substitution are given. Which one is most deactivating? *(2013)*

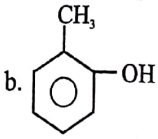
a. — COOH b. $-NO_2$
c. $-C \equiv N$ d. $-SO_3H$

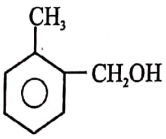
63. Which of the following species is not electrophilic in nature? *(2010 Mains)*

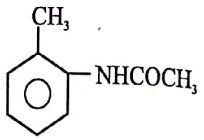
a. b. BH_3
c. d.

64. Which one is most reactive towards electrophilic reagent? [MR*] *(2010 Pre)*

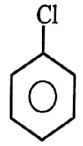
a. 

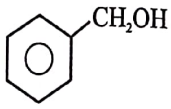
b. 

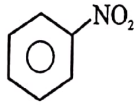
c. 

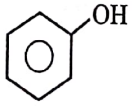
d. 

65. Which one the following is most reactive towards electrophilic attack? *(2008)*

a. 

b. 

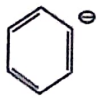
c. 

d. 

66. The relative reactivities of acyl compounds towards nucleophilic substitution are in the order of: *(2008)*

a. Acyl chloride > Ester > Acid anhydride > Amide
b. Acyl chloride > Acid anhydride > Ester > Amide
c. Ester > Acyl chloride > Amide > Acid anhydride
d. Acid anhydride > Amide > Ester > Acyl chloride

67. The stability of carbanions in the following

(i) $RC \equiv C^{\ominus}$ (ii) 

(iii) $R_2C=\overset{\ominus}{C}H$ (iv) $R_3C-\overset{\ominus}{C}H_2$

is in the order of: [MR*] *(2008)*

a. (iv) > (ii) > (iii) > (i) b. (i) > (iii) > (ii) > (iv)
c. (i) > (ii) > (iii) > (iv) d. (ii) > (iii) > (iv) > (i)

68. The order of decreasing reactivity towards an electrophilic reagent, for the following would be: *(2007)*
(i) Benzene (ii) Toluene
(iii) Chlorobenzene (iv) Phenol
a. (ii) > (iv) > (i) > (iii) b. (iv) > (iii) > (ii) > (i)
c. (iv) > (ii) > (i) > (iii) d. (i) > (ii) > (iii) > (iv)

69. For (i) I^-, (ii) Cl^-, (iii) Br^-, the increasing order of nucleophilicity would be: *(2007)*
a. $Cl^- < Br^- < I^-$ b. $I^- < Cl^- < Br^-$
c. $Br^- < Cl^- < I^-$ d. $I^- < Br^- < Cl^-$

70. Which amongst the following is the most stable carbocation? *(2005)*
a. $\overset{+}{C}H_3$ b. $CH_3\overset{+}{C}H_2$
c. $CH_3-\overset{+}{C}H(CH_3)$ d. $CH_3C^+(CH_3)_2$

71. Which of the following orders of acid strength is correct? *(2003)*
a. RCOOH > ROH > HOH > HC ≡ CH
b. RCOOH > HOH > ROH > HC ≡ CH
c. RCOOH > HOH > HC ≡ CH > ROH
d. RCOOH > HC ≡ CH > HOH > ROH

72. Which one of the following orders is correct regarding the effect of the substituents? *(1998)*
a. $-NR_2 < -OR > -F$ b. $-NR_2 > -OR > -F$
c. $-NR_2 > -OR < -F$ d. $-NR_2 < -OR < -F$

73. The most reactive compound for electrophilic nitration is: *(1992)*
a. Benzene b. Nitrobenzene
c. Benzoic acid d. Toluene

74. Which of the following is the most stable carbocation (carbonium ion)? *(1991)*
a. $CH_3CH_2^+$ b. $(CH_3)_2\overset{+}{C}H$
c. $(CH_3)_3\overset{+}{C}$ d. $C_6H_5\overset{+}{C}H_2$

75. Cyclic hydrocarbon 'A' has all the carbon and hydrogen atoms in a single plane. All the carbon -carbon bonds have the same length, less than 1.54 Å, but more than 1.34 Å. The bond angle will be: *(1989)*
a. 109°28' b. 100°
c. 180° d. 120°

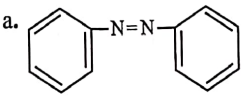
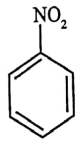
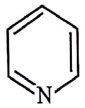
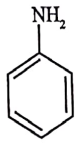
Methods of Purification, Qualitative and Quantitative Analysis of Organic Compounds

76. In Lassaigne's extract of an organic compound, both nitrogen and sulphur are present, which gives blood red colour with Fe^{3+} due to the formation of [MR*] *(2023)*
a. $[Fe(SCN)]^{2+}$ b. $Fe_4[Fe(CN)_6]_3.xH_2O$
c. NaSCN d. $[Fe(CN)_5NOS]^{4-}$

77. Match **List-I** with **List-II** [MR*] *(2023-Manipur)*

	List-I (Mixtures/Sample)		List-II (Technique used for purification)
A.	Glycerol from spent lye	I.	Steam distillation
B.	Chloroform + Aniline	II.	Fractional distillation
C.	Fraction of crude oil	III.	Distillation under reduced pressure
D.	Aniline + Water	IV.	Distillation

Choose the **correct** answer from the options given below:
a. A-III, B-IV, C-II, D-I b. A-IV, B-II, C-I, D-III
c. A-I, B-II, C-III, D-IV d. A-I, B-III, C-II, D-IV

78. The Kjeldahl's method for the estimation of nitrogen **can be used** to estimate the amount of nitrogen in which one of the following compounds? [MR*] *(2022)*
a. 
b. 
c. 
d. 

79. Paper chromatography is an example of: *(2020)*
a. Partition chromatography
b. Thin layer chromatography
c. Column chromatography
d. Adsorption chromatography

80. A liquid compound (x) can be purified by steam distillation only if it is *(2020-Covid)*
a. Not steam volatile, miscible with water
b. Steam volatile, miscible with water
c. Not steam volatile, immiscible with water
d. Steam volatile, immiscible with water

81. The most suitable method of separation of 1 : 1 mixture of ortho and para-nitrophenols is *(2017-Delhi)*
a. Steam distillation b. Sublimation
c. Chromatography d. Crystallisation

82. In Duma's method for estimation of nitrogen, 0.25 g of an organic compound gave 40 mL of nitrogen collected at 300 K temperature and 725 mm pressure. If the aqueous tension at 300 K is 25 mm, the percentage of nitrogen in the compound is: [MR*] *(2015)*
a. 18.20 b. 16.76
c. 15.76 d. 17.36

83. In the Kjeldahl's method for estimation of nitrogen present in a soil sample, ammonia evolved from 0.75 g of sample neutralised 10 mL of 1 M H_2SO_4. The percentage of nitrogen in the soil is [MR*] *(2014)*
a. 45.33 b. 35.33
c. 43.33 d. 37.33

84. In Dumas' method of estimation of nitrogen 0.35 g of an organic compound gave 55 mL of nitrogen collected at 300 K temperature and 715 mm pressure. The percentage composition of nitrogen in the compound would be: *(2011 Pre)*
(Aqueous tension at 300 K = 15 mm)
a. 14.45 b. 15.45
c. 16.45 d. 17.45

85. The Lassaigne's extract is boiled with conc. HNO_3 while testing for halogens. By doing so, it: *(2011 Pre)*
a. Decomposes Na_2S and NaCN, formed
b. Helps in the precipitation of AgCl
c. Increases the solubility product of AgCl
d. Increases the concentration of NO_3^- ions

86. The best method for the separation of naphthalene and benzoic acid from their mixture is: *(2005)*
a. Chromatography b. Crystallisation
c. Distillation d. Sublimation

87. In steam distillation of toluene, the pressure of toluene in vapour is: *(2001)*
a. Equal pressure of barometer
b. Less than pressure of barometer
c. Equal to vapour pressure to toluene in simple distillation
d. More than vapour pressure of toluene in simple distillation

88. Which of the following technique is most suitable for purification of cyclohexanone from a mixture containing benzoic acid, isoamyl alcohol, cyclohexane and cyclohexanone? **[OS]** *(1997)*
a. Sublimation b. Evaporation
c. Crystallisation d. IR spectroscopy

89. In sodium fusion test of organic compounds, the nitrogen of the organic compound is converted into: *(1991)*
a. Sodamide b. Sodium cyanide
c. Sodium nitrite d. Sodium nitrate

90. Kjeldahl's method is used in the estimation of: *(1990)*
a. Nitrogen b. Halogens
c. Sulphur d. Oxygen

91. Lassaigne's test is used in qualitative analysis to detect: *(1989)*
a. Nitrogen b. Sulphur
c. [illegible] d. All of these

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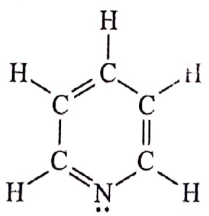
1. (d)	**2.** (b)	**3.** (d)	**4.** (c)	**5.** (d)	**6.** (b)	**7.** (b)	**8.** (c)	**9.** (d)	**10.** (b)
11. (d)	**12.** (d)	**13.** (d)	**14.** (a)	**15.** (d)	**16.** (c)	**17.** (a)	**18.** (b)	**19.** (b)	**20.** (d)
21. (b)	**22.** (a)	**23.** (b)	**24.** (b)	**25.** (c)	**26.** (b)	**27.** (b)	**28.** (c)	**29.** (d)	**30.** (d)
31. (a)	**32.** (b)	**33.** (a)	**34.** (a)	**35.** (a)	**36.** (b)	**37.** (b)	**38.** (a)	**39.** (c)	**40.** (a)
41. (a)	**42.** (c)	**43.** (b)	**44.** (a)	**45.** (d)	**46.** (c)	**47.** (b)	**48.** (b)	**49.** (d)	**50.** (a)
51. (c)	**52.** (d)	**53.** (a, b)	**54.** (a)	**55.** (d)	**56.** (b)	**57.** (b)	**58.** (a)	**59.** (b)	**60.** (c)
61. (c)	**62.** (b)	**63.** (c)	**64.** (b)	**65.** (d)	**66.** (b)	**67.** (c)	**68.** (c)	**69.** (a)	**70.** (d)
71. (b)	**72.** (d)	**73.** (d)	**74.** (c)	**75.** (d)	**76.** (a)	**77.** (a)	**78.** (d)	**79.** (a)	**80.** (d)
81. (a)	**82.** (b)	**83.** (d)	**84.** (c)	**85.** (a)	**86.** (d)	**87.** (b)	**88.** (d)	**89.** (b)	**90.** (a)
91. (d)									

Explanations

1. (d) The structure of pyridine is:



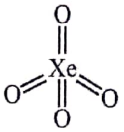
Hence, it has 11 sigma, 3 π bonds and one lone pair.

2. (b) Carbon atoms attached to one double bond are sp^2 hybridized and carbon atoms attached to a triple bond are sp hybridized.

$$\overset{sp^2}{C}H_2 = \overset{sp^2}{C}H - \overset{sp}{C} \equiv \overset{sp}{C}H$$

Number of orbital require in hybridisation = Number of σ-bonds around each carbon atom.

3. (d) In the given species, xenone tetraoxide contains equal number of sigma and pi-bonds that is 4 – σ and 4 – π bonds. This is shown as,



4. (c) The molecule is called en/ol, i.e. enol, because it has a C=C group and an –OH group. In the given structures first structure is an enolic form and it has 18 σ-bonds and 2 π-bonds are present

5. (d) The number of electrons involved in the formation of pi bonds are called pi-electrons.

Pi bonds are always formed with sigma bonds means a double bond always contains one sigma and one pi bond. There are four double bond.

Hence, no. of π-electrons = 2 × 4 = 8.

6. (b) In the given compounds, the linear compound is

$$\underset{sp}{CH_3}-\underset{sp}{C}\equiv\underset{sp}{C}-CH_3$$

7. (b) Acidic strength ∝ % s-character and % s-character is decided by types of hybridisation.

The conjugate base of a weak acid is the strong base and vice-versa.

Therefore, the order of acidic strength would be:

$$\underset{sp}{H-C}\equiv\underset{sp}{C}-H > \underset{sp^2}{CH_2}=\underset{sp^2}{CH_2} > \underset{sp^3}{CH_3}-\underset{sp^3}{CH_3}$$

(Acidic character)

Conjugate base of the given acid is as follows:

$$C^{\ominus}C-H < {}^{\ominus}CHCH_2 < {}^{\ominus}CH_2-CH_3$$

(Basic character)

(iii) > (ii) > (i)

Hence, the order of base strength would be just the reverse of it:

(i) > (ii) > (iii)

8. (c) $\underset{6}{CH_3}-\underset{5}{CH}=\underset{4}{CH}-\underset{3}{CH_2}-\underset{2}{C}\equiv\underset{1}{CH}$

Hybridisation state of 1,3,5 carbon are sp, sp^3 & sp^2.

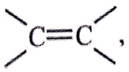
9. (d) $\underset{\downarrow}{CH_3}-\underset{\downarrow}{CH}=\underset{\downarrow}{CH}-\underset{\downarrow}{CH_3}$

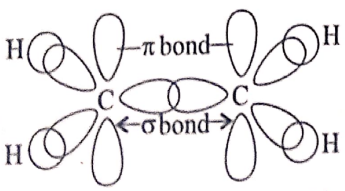
sp^3 sp^2 sp^2 sp^3

10. (b) Sigma bond is stronger than π-bond because of better overlap. All single bonds are σ bonds and all multiple bonds contain one σ and other π bonds.

11. (d) Angle increases progressively, given as:

sp^3 (109°28'), sp^2(120°), sp(180°)

12. (d) 



Restricted rotation is due to sideways overlap of two *p*-orbitals.

13. (d) Shortest C – C distance (1.20 Å) is in acetylene. C ≡ C are shorter than C = C ($sp^2 - sp^2$; $sp^2 - sp$ and $sp - sp$) and C – C (all type of bonds.)

14. (a) sp^3 orbital has 1/4 (25%) *s*-character.

15. (d) The structural formula of straight chain hydrocarbon C_8H_{10} is given as, $\overset{sp^3}{CH_3}\overset{sp^2}{CH}=\overset{sp^2}{CH}\overset{sp^3}{CH_2}-\overset{sp^2}{CH}=\overset{sp^2}{CH}\overset{sp}{C}\equiv\overset{sp}{CH}$

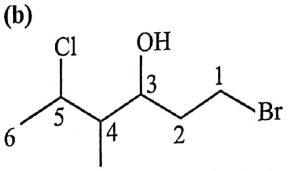
16. (c) $\overset{sp^2}{CH_2}=\overset{sp}{C}=\overset{sp^2}{CH_2}$

17. (a) Tetrachloroethene being an alkene has sp^2 -hybridised C-atoms and hence the angle Cl – C – Cl is 120° while in tetrachloromethane, carbon sp^3 -hybridized, therefore the angle Cl – C – Cl is 109°28′.

18. (b) $\underset{5}{OHC}-\underset{4}{CH}=\underset{3}{CH}-\underset{2}{CH_2}-\underset{1}{COOCH_3}$

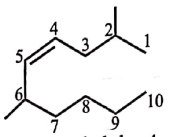
Since, the ester group has more priority than that of aldehyde group. Hence, so numbering should be done from right to left. C_1 has double bond and is sp^2 hybridised and C_2 is sp^3 hybridised.

19. (b)



1-Bromo-5-chloro-4-methylhexan-3-ol

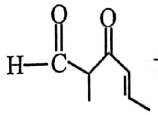
20. (d) By following IUPAC rules of nomenclature the correct structure of 2,6-Dimethyl-dec-4-ene is:



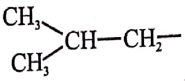
2,6-Dimethyl-dec-4-ene

21. (b) The order of decreasing priority for some functional groups is:

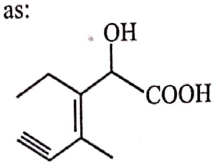
–COOH, $-SO_3H$, –COOR, –COCl, $-CONH_2$, –CN, –HC = O, > C = O, –OH, $-NH_2$, > C = C<, $-C\equiv C-$.

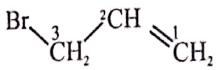


→ 3–keto–2–methylhex–4–enal

22. (a) Isobutyl group is represented as: 

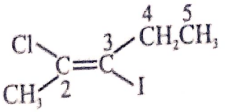
23. (b) Structure of 3-Ethyl-2-hydroxy-4-methylhex-3-en-5-ynoic acid is given as:



24. (b) 

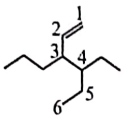
IUPAC name should be 3-Bromo prop –1–ene as double bond (=) is given priority over halogen group & is numbered first.

25. (c) In the given compound chloro and iodo-groups (halogen groups) are present opposite to each other of the double bond. Therefore, trans-word will be used in numbering and according to the IUPAC nomenclature system chloro will come before iodo. Therefore the correct name is,



Trans 2–chloro-3–iodo–2–pentene.

26. (b)



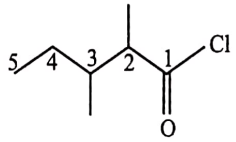
Nomencalture: 4-ethyl-3-propyl hex-1-ene

27. (b) Pent–1–yn–3-ene is wrong, Pent–3–en–1-yne is correct (alphabetic rule).

28. (c) $\overset{4}{C}H \equiv \overset{3}{C} - \overset{2}{C}H = \overset{1}{C}H_2$

IUPAC name is 1-butene-3-yne. Double bond is given priority over triple bond.

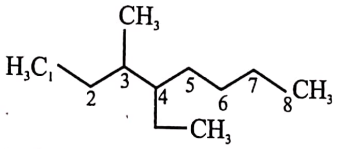
29. (d) The given compound contains COCl (-oyl chloride) group therefore, the IUPAC name of the given structure is,



2,3 dimethyl pentanoyl chloride

30. (d) 3-methyl-4-ethyl heptane is wrong, it should be 4-ethyl-3-methyl heptane as alphabetic rule was violated (chronological rule). This should be 4-ethyl-3-methyl heptane

31. (a)

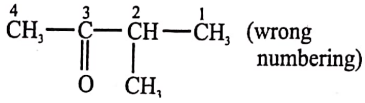


4-ethyl-3-methyloctane

32. (b) $\overset{1}{C}H_2 = \overset{2}{C}H - \overset{3}{C}H_2 - \overset{4}{C}H_2 - \overset{5}{C} \equiv \overset{6}{C}H$

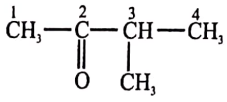
1-hexene-5-yne.

33. (a)



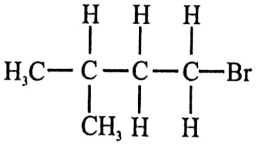
(wrong numbering)

The $-\overset{O}{\overset{\|}{C}}-$ group should get priority over methyl group correct IUPAC name



3-methyl-2-butanone

34. (a)

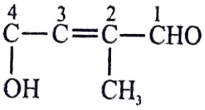


1-Bromo-3-methylbutane

35. (a) $\overset{7}{C}H_3 - \overset{6}{C}H = \overset{5}{C}H - \overset{4}{C}H_2 - \overset{3}{C}H - \overset{2}{C}H_2 - \overset{1}{C}OOH$ with NH_2 on C-3

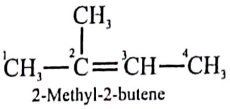
As – COOH group is highest priority group, it is numbered one. So, the IUPAC name is 3-amino-5-heptenoic acid.

36. (b)



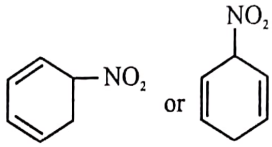
4-hydroxy-2-methyl pent-2-ene-1-al

37. (b)



2-Methyl-2-butene

38. (a)



Hence it is homocyclic (as the ring system is made of one type of atoms, *i.e.* carbon) but not aromatic.

For aromaticity, any compound should follow Huckel's rule.

39. (c) A type of isomerism in which compounds having the same molecular formula but different alkyl groups on either side of functional groups is called metamerism. Among the given options, compounds with molecular formula $C_4H_{10}O$ can be ethers and may exhibit metamerism. i.e.,

$CH_3-O-\underset{CH_3}{\underset{|}{CH}}-CH_3$ (methoxy propane), and $CH_3-CH_2-O-CH_2-CH_3$ (ethoxy ethane). These are metamers because they have different structure of alkyl chains around the functional group.

40. (a) α-H at bridge carbon never participate in tautomerism. Thus, only (III) shows tautomerism.

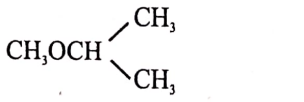
41. (a) Only 4 structural isomers are possible for diphenyl methane when one of the hydrogens is replaced by a chlorine atom.

42. (c) Geometrical isomers are those isomers which posses the same molecular & structural formula but differ in the arrangement of atom.

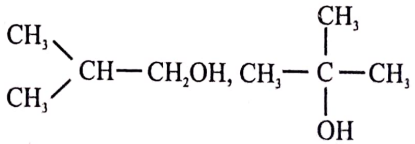
43. (b) It is a special type of functional isomerism, in which both the isomers are represented by one and the same substance and are always present in equilibrium. It is exhibited by nitroalkane (RCH_2NO_2) and isonitroalkane.

44. (a) There are 7 isomers in $C_4H_{10}O$. Out of these 4 are alcohols and 3 are ethers.

$CH_3CH_2-O-CH_2CH_3$, $CH_3OCH_2CH_2CH_3$

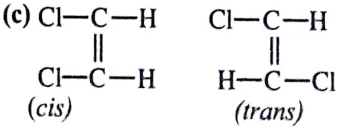


$CH_3CH_2CH_2CH_2OH$, $CH_3\,CH_2\underset{OH}{\underset{|}{CH}}-CH_3$



45. (d) Isomers must have same molecular formula but different structural formula.

46. (c)



1, 2 -dichloroethene exhibits *cis-trans* (geometrical) isomerism

47. (b) 5-Chain isomers are obtained from alkane C_6H_{14}.

(i) $CH_3CH_2CH_2CH_2CH_2CH_3$

(ii) $CH_3-\underset{\underset{CH_3}{|}}{CH}-CH_2-CH_2-CH_3$

(iii) $CH_3-\underset{\underset{CH_3}{|}}{\overset{\overset{CH_3}{|}}{C}}-CH_2CH_3$

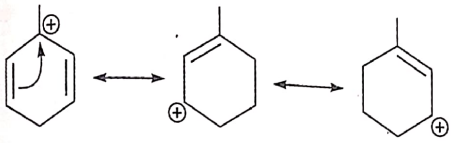
(iv) $CH_3-\underset{\underset{CH_3}{|}}{CH}-\underset{\underset{CH_3}{|}}{CH}-CH_3$

(v) $CH_3CH_2\underset{\underset{CH_3}{|}}{CH}.CH_2CH_3$

48. (b) Statement-I is false as electromeric effects predominates over inductive effect.

49. (d) Due to high electronegativity, halogens are electron withdrawing in nature. They have high electron withdrawing inductive effect. Halogens show both electron withdrawing inductive effect and electron donating resonance effect, in electrophilic substitution reaction, but inductive effect overpowers resonance effect so, it deactivates benzene ring and directs the, therefore incoming electrophile to ortho and para positions. Hence, here assertion is correct and Reason is incorrect.

50. (a) Stability of carbocation ∝ Number of α-Hydrogen ∝ Number of resonating structures



Hence, among the given structures, structure (1) is most stable.

51. (c) Here, the stability of carbocations is decided by the presence of alpha hydrogens.

Alpha hydrogens are the hydrogen atoms directly attached the alpha carbon in an organic molecule. An alpha carbon is a carbon that is adjacent to a functional group, such as carbocationic carbon here.

$H_3C-\underset{\underset{\oplus}{|}}{\overset{\overset{CH_3}{|}}{C}}-CH_3$ Tertiary butyl carbocation (9 α-H atoms)

$H_3C-\overset{\oplus}{\underset{|}{CH}}-CH_2-CH_3$ Secondary butyl carbocation (5 α-H atoms)

A tertiary butyl carbocation has 9 alpha hydrogen atoms whereas secondary butyl carbocation has 5 alpha hydrogen atoms.

So when more number of α-H atoms is present, more will be the hyperconjugation effect hence more will be the stability of carbocation.

Thus tertiary butyl carbocation is more stable than a secondary butyl carbocation due to hyperconjugation

52. (d) NO_2 group exhibit –I effect and it decreases with increase in distance with respect to positive charge. In option (d), positive charge present on C atom at maximum distance so –I effect reaching to it is minimum and stability is maximum.

53. (a, b) –I effect increases on increasing electronegativity of atom. So, correct order of –I effect is

$-NH_2 < -OR < -F$.

Also $-NR_2 < -OR < -F$

54. (a) Electrophile can be either neutral or positively charged species and can form a bond by accepting a pair of electrons from nucleophile.

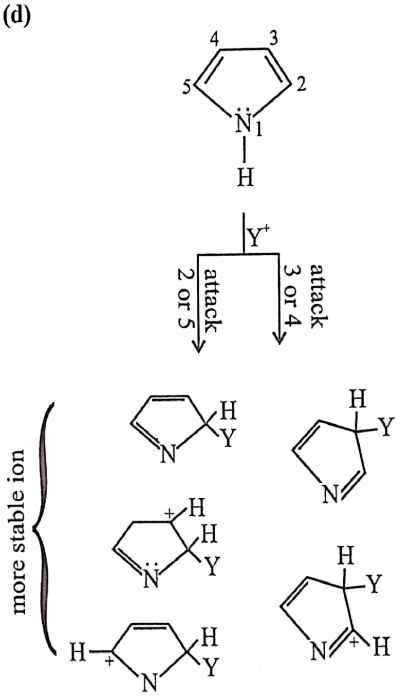
An electron loving species is called electrophile.

Electrophile: Electron can be accepted by positively charged or neutral species.

A nucleus loving species are called nucleophiles.

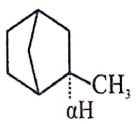
Nucleophile: A negatively charged species or neutral species can accepted by positive charge or donate their electron to positively charge species or neutral species.

55. (d)



56. (b) Nucleophiles are positive charge loving species or electron rich compounds. Lewis acids are those species which are electron deficient so nucleophiles cannot act as Lewis acids, they instead are Lewis bases.

57. (b) Hyperconjugation provides extra stability by removal of H from α carbon which is only possible in:

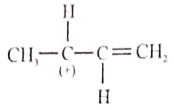


58. (a)

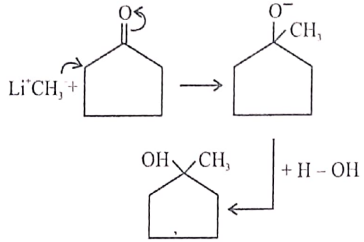
$CH_3-\overset{\overset{CH_3}{|}}{\underset{\underset{CH_3}{|}}{C^{(+)}}}$

3° carbocation is most stable than benzyol carbocation because of 9 hyper-conjugation of 3 inductive effects of $-CH_3$.

59. **(b)** So, the new species formed will be resonance stabilised (alternating positive and negative charge).



60. **(c)**

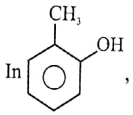


61. **(c)** NO_2 is an electron withdrawing group, it will favour nucleophilic attack.

62. **(b)** $-NO_2$ is most deactivating due to -I and -M effect.

63. **(c)** H_3O^+ has lone pair of electrons for donation, hence it is not electron deficient in nature and therefore, it does not behave like an electrophile. But NO_2^+, Cl^+ act as powerful electrophiles in substitution reactions whereas BH_3 is an electron deficient compound.

64. **(b)** Electrophilic reagent are electron seeking species.



, lone pair on oxygen are in conjugation with benzene ring, which makes it suitable for an electrophilic attack.

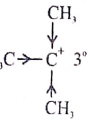
65. **(d)** Electrophilic attack means reagent should be electron deficient and positively charged. Lone pair of electron on oxygen in phenol ring increases the negativity on benzene ring thus making it most reactive towards electrophilic attack.

66. **(b)** For nucleophilicity [the attacking reagent having (–ve) charge], C atom attached to an electron withdrawing group or atom, should be a better leaving group. Weaker the base better the leaving group it becomes.
Order becomes: Acyl chloride > Acid anhydride > Ester > Amide.

67. **(c)** The carbanion with more s-character is more stable. Hence, the order of stability would be : (i) > (ii) > (iii) > (iv)

68. **(c)** Electrophiles have high affinity for electrons. They attack the site where electron-density is highest. Electron withdrawing substances increases the electron density. The electron withdrawing tendency decreases in the order:
$-OH > -CH_3 > -H > -Cl$
Therefore, the correct order of reactivity towards electrophiles is:
$C_6H_5OH > C_6H_5CH_3 > C_6H_6 > C_6H_5Cl$

69. **(a)** Larger the atomic mass $\propto$ nuleophilicity

70. **(d)** 

71. **(b)** RCOOH > HOH > ROH > HC≡CH
Carboxylic acid is the strongest acid than water & al
Acetylene is also weakest acid.

72. **(d)** The electronegativity follow the order:
N > O > F. So due to electronegativity character the or
– I effect is $-NR_2 < -OR < -F$

73. **(d)** For electrophilic nitration, most reactive compou
toluene. As CH_3 is electron donating in nature, (+*I* , e
resulting into higher electron density in the ring than ber
nitrobenzene and benzoic acid.

74. **(c)** 3° > 2° > 1° more the delocalisation of positive ch
more is its stability.

75. **(d)** All the properties mentioned in the question sugges
it is a benzene molecule. Since in benzene all carbons a
-hybridised, therefore, C – C – C angle is 120°

76. **(a)** In case, nitrogen and sulphur both are present
organic compound, sodium thiocyanate is formed.

$Na + C + N + S \rightarrow NaSCN$

Which further reacts as:

$Fe^{3+} + SCN^- \rightarrow [Fe(SCN)]^{2+}$
(Blood red color)

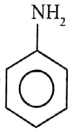
77. **(a)**

(A) Glycerol from spent lye → Distillation under red
pre

(B) Chloroform + Aniline → Distillation

(C) Fractions of crude oil → Fractional distillation

(D) Aniline + H_2O → Steam distillation

78. **(d)** 

Kjeldahl's method is not applicable to the compounds conta
nitrogen having nitro and azo group and nitrogen present i
ring (pyridine), as nitrogen of these compounds does not ch
to ammonium sulphate under these conditions.

79. **(a)** The example of partition chromatography is seen in p
chromatography.
In this process, chromatography paper is used as a statio
phase which is suspended in a mixture of solvents that a
a mobile phase.

80. **(d)** Steam distillation technique is applied to separate
substances which are steam volatile and immiscible with w

81. **(a)** The most suitable method of separation of 1 : 1 mix
of ortho and para - nitrophenol is steam distillation, bec
there is large difference in the boiling point of ortho and
position as ortho form intra hydrogen bonding and para f
inter-molecular hybrogen bonding.

82. **(b)** According to Duma's method:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Rightarrow V_1 = \frac{P_2V_2T_1}{P_1T_2}$$

$$\frac{(725-25)\times 40}{300}=\frac{760V_2}{273}$$

$V_2 = 33.53$ ml

$$\text{Mass} = \frac{33.53}{22400}\times 28 = 0.042 \text{ g}$$

$$\%\,N = \frac{28\times V\times 100}{22400\times m}$$

$$\%\text{ of nitrogen} = \frac{0.042}{0.25}\times 100 = 16.76\%$$

83. (d) Kjeldahl's method is used for estimation of N in organic sample where

$$\%N = \frac{1.4\times N\times V}{w}$$

N = Normality of acid $H_2SO_4 = 2$

w = weight of NH_3 evolved

V = Vol. of H_2SO_4

$$= \frac{1.4\times 10\times 2}{0.75} = 37.33\%$$

84. (c) For Duma's method:

$$\frac{P_1V_1}{T_1}=\frac{P_2V_2}{T_2} \Rightarrow V_2 = \frac{P_1V_1T_2}{P_2T_1}$$

(Vol. of N at STP) $V_2 = \frac{700\times 55\times 273}{760\times 300} = 46.09$ mL

$$\%N = \frac{28\times V\times 10}{22400\times m}$$

$$\%N = \frac{28\times 46.09\times 100}{22400\times 0.35} = 16.450\%$$

85. (a) In lassaigne's test of halogens, it's necessary to remove sodium cyanide and sodium sulphide from the solution.

$NaCN + HNO_3 \rightarrow NaNO_3 + HCN\uparrow$

$Na_2S + 2\,HNO_3 \rightarrow 2NaNO_3 + H_2S\uparrow$

86. (d) Naphthalene gets sublimised quickly & thus can be separated from benzoic acid, by the technique called sublimation.

87. (b) In steam distillation of toluene, the pressure of toluene in vapour is less than pressure of barometer, steam distillation is essentially co-distillation with water and is carried out when a solid or liquid is insoluble in water and is volatile with steam but the impurities are non – volatile.

88. (d) In the IR spectroscopy, each functional group appears at a certain peak (in cm^{-1}). So, cyclohexanone can be identified by carbonyl peak.

89. (b) Sodium cyanide (Na + C + N → NaCN).

90. (a) Kjeldahl's method is used in the estimation of nitrogen.

91. (d) All the three (N, S, halogens).

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CHAPTER 10

Hydrocarbons

Alkanes

1. Weight (g) of two moles of the organic compound, which is obtained by heating sodium ethanoate with sodium hydroxide in presence of calcium oxide is: *(2023)*

a. 18 b. 16
c. 32 d. 30

2. The decreasing order of boiling points of the following alkanes is: [**MR***] *(2022 Re)*

(a) heptane (b) butane
(c) 2-methylbutane (d) 2-methylpropane
(e) hexane

Choose the **correct answer** from the options given below :

a. (a) > (e) > (c) > (b) > (d)
b. (a) > (c) > (e) > (d) > (b)
c. (c) > (d) > (a) > (e) > (b)
d. (a) > (e) > (b) > (c) > (d)

3. Dihedral angle of least stable conformer of ethane is: *(2021)*

a. 180° b. 60°
c. 0° d. 120°

4. Which of the following alkane cannot be made in good yield by Wurtz reaction? [**MR***] *(2020)*

a. 2, 3-Dimethylbutane b. *n*-Heptane
c. *n*-Butane d. *n*-Hexane

5. Which of the following is a free radical substitution reaction? *(2020-Covid)*

a. Acetylene with HBr
b. Methane with Br_2/hv
c. Propene with HBr/$(C_6H_5COO)_2$
c. Benzene with $Br_2/AlCl_3$

6. Hydrocarbon (A) reacts with bromine by substitution to form an alkyl bromide which by Wurtz reaction is converted to gaseous hydrocarbon containing less than four carbon atoms. (A) is *(2018)*

a. CH ≡ CH b. $CH_2 = CH_2$
c. CH_4 d. $CH_3 - CH_3$

7. With respect to the conformers of ethane, which of the following statements is true? *(2017-Delhi)*

a. Both bond angles and bond length remains same
b. Bond angle remains same but bond length changes
c. Bond angle changes but bond length remains same
d. Both bond angle and bond length change

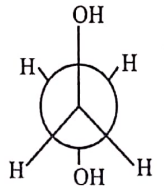
8. The correct statement regarding the comparison of staggered and eclipsed conformations of ethane, is: [**MR***] *(2016-I)*

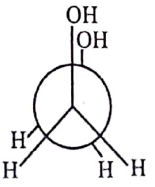
a. The staggered conformation of ethane is more stable than eclipsed conformation, because staggered conformation has no torsional strain.
b. The staggered conformation of ethane is less stable than eclipsed conformation, because staggered conformation has torsional strain.
c. The eclipsed conformation of ethane is more stable than staggered conformation, because eclipsed conformation has no torsional strain.
d. The eclipsed conformation of ethane is more stable than staggered conformation even though the eclipsed conformation has torsional strain.

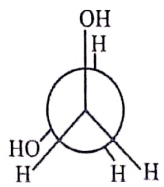
9. The number of structural isomers possible from the molecular formula C_3H_9N is: *(2015 Re)*

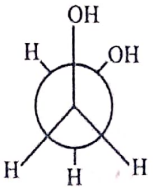
a. 3 b. 4
c. 5 d. 2

10. Which of the following conformers for ethylene glycol is most stable? *(2010 Main)*

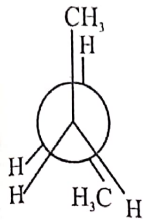
a. 

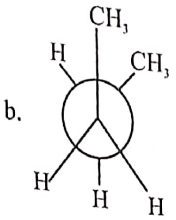
b. 

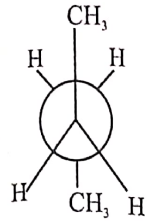
c. 

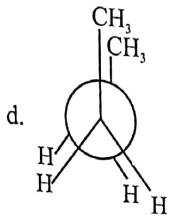
d. 

11. In the following, the most stable conformation of *n*-butane is: *(2010 Pre)*

a. 

b. 

c. 

d. 

12. Liquid hydrocarbons can be converted to a mixture of gaseous hydrocarbons by: *(2010 Pre)*

a. Hydrolysis
b. Oxidation
c. Cracking
d. Distillation under reduced pressure

13. Dihedral angle in staggered form of ethane is: *(2000)*

a. 0° b. 120°
c. 60° d. 180°

14. Which of the following reaction is expected to readily give a hydrocarbon product in good yields? *(1997)*

a. $CH_3CH_3 \xrightarrow[h\nu]{Cl_2}$ b. $(CH_3)_2CHCl \xrightarrow{C_2H_5OH}$

c. $RCOOK \xrightarrow[\text{Oxidation}]{\text{Electrolysis}}$ d. $RCOOAg \xrightarrow{I_2}$

15. In the commercial gasolines, the type of hydrocarbons which are more desirable is: *(1997)*

a. Linear unsaturated hydrocarbon
b. Toluene
c. Branched hydrocarbon
d. Straight-chain hydrocarbon

16. The most stable conformation of *n*-butane is: **[MR*]** *(1997)*

a. Gauche b. Staggered
c. Skew boat d. Eclipsed

17. Reactivity of hydrogen atoms attached to different carbon atoms in alkanes has the order. *(1993)*

a. Tertiary > primary > secondary
b. Primary > secondary > tertiary
c. Both (a) and (b)
d. Tertiary > secondary > primary

Alkenes

18. Which amongst the following compounds will show geometrical isomerism? **[MR*]** *(2023-Manipur)*

a. Pent-1-ene b. 2, 3-Dimethylbut-2 ene
c. 2-Methylprop-1-ene d. 3, 4-Dimethylhex-3-ene

19. The **incorrect** method for the synthesis of alkenes is: **[MR*]** *(2022 Re)*

a. treating vicinal dihalides with Zn metal
b. treatment of alkynes with Na in liquid NH_3
c. heating alkyl halides with alcoholic KOH
d. treating alkyl halides in aqueous KOH solution

20. Compound X on reaction with O_3 followed by Zn/H_2O gives formaldehyde and 2-methyl propanal as products. The compound X is: **[MR*]** *(2022)*

a. Pent-2-ene b. 3-Methylbut-1-ene
c. 2-Methylbut-1-ene d. 2-Methylbut-2-ene

21. The major product of the following chemical reaction is: **[MR*]** *(2021)*

$$(CH_3)_2CH-CH=CH_2 + HBr \xrightarrow{(C_6H_5CO)_2O_2} ?$$

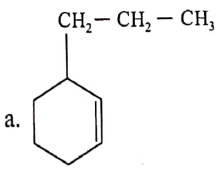
a. $(CH_3)_2CH-CH_2-CH_2-O-COC_6H_5$

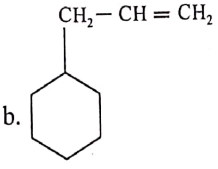
b. $(CH_3)_2CH-\underset{\displaystyle Br}{\underset{|}{CH}}-CH_3$

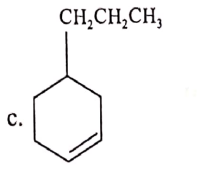
c. $(CH_3)_2CBr-CH_2-CH_3$

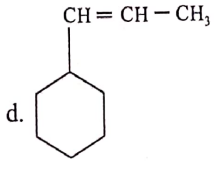
d. $(CH_3)_2CH-CH_2-CH_2-Br$

22. An alkene on ozonolysis gives methanal as one of the product. Its structure is: *(2020)*

a. 

b. 

c. 

d. 

23. An alkene "A" on reaction with O_3 and $Zn - H_2O$ gives propanone and ethanal in equimolar ratio. Addition of HCl to alkene "A" gives "B" as the major product. The structure of product "B" is: *(2019)*

a. $Cl-CH_2-CH_2-\underset{\displaystyle CH_3}{\underset{|}{CH}}$ b. $H_3C-CH_2-\underset{\displaystyle CH_2Cl}{\underset{|}{CH}}-CH_3$

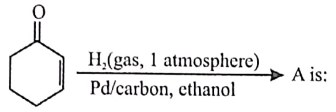
c. $H_3C-CH_2-\underset{\displaystyle Cl}{\underset{|}{C}}-CH_3$ d. $H_3C-\underset{\displaystyle Cl}{\underset{|}{CH}}-\underset{\displaystyle CH_3}{\underset{|}{CH}}$

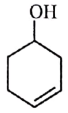
24. The compound that will react most readily with gaseous bromine has the formula: *(2016 - II)*

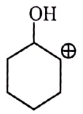
a. C_4H_{10} b. C_2H_4

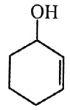
c. C_3H_6 d. C_2H_2

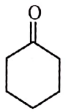
25. The correct structure of the product A formed in the reaction: *(2016 - II)*



a. 

b. 

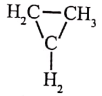
c. 

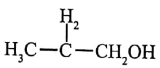
d. 

26. Which of the following compounds shall not produce propene by reaction with HBr followed by elimination or direct only elimination reaction? *(2016 - II)*

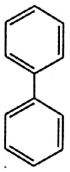
a. $H_2C{=}C{=}O$

b.

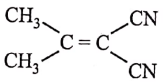
c. 

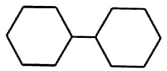
d. 

27. In which of the following molecules, all atoms are coplanar? *(2016 - II)*

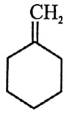
a. 

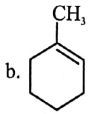
b.

c. 

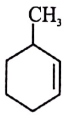
d. 

28. In the reaction with HCl, an alkene reacts in accordance with the Markovnikov's rule, to give a product 1-chloro-1-methylcyclohexane. The possible alkene is: *(2015 Re)*

a. 

b. 

c. (a) and (b)

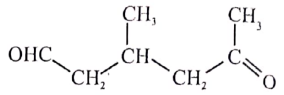
d. 

29. 2, 3-Dimethyl-2-butene can be prepared by heating which of the following compounds with a strong acid? *(2015 Re)*

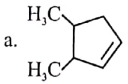
a. $(CH_3)_3CCH{=}CH_2$ b. $(CH_3)_2C{=}CHCH_2CH_3$

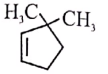
c. $(CH_3)_2CHCH_2CH{=}CH_2$ d.

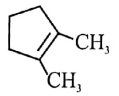
30. A single compound of the structure

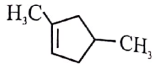


is obtainable from ozonolysis of which of the following cyclic compounds? *(2015)*

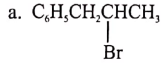
a. 

b. 

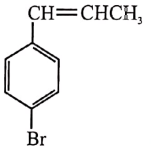
c. 

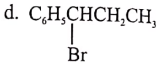
d. 

31. The reaction of $C_6H_5CH = CHCH_3$ with HBr produces: *(2015)*

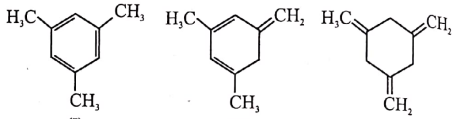
a. 

b. $C_6H_5CH_2CH_2CH_2Br$

c. 

d. 

32. Given:

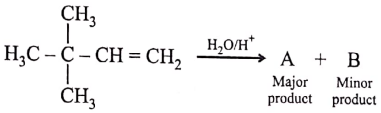


The enthalpy of hydrogenation of these compounds will be in the order as: *(2015)*

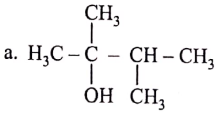
a. III > II > I b. II > III > I

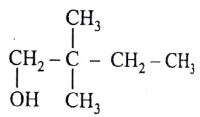
c. II > I > III d. I > II > III

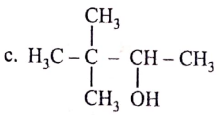
33. In the following reaction [**MR***] *(2012*

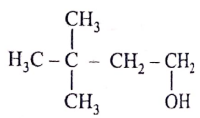


The major product is

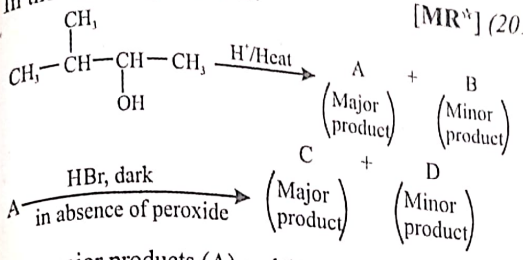
a. 

b. 

c. 

d. 

34. In the following reactions: [MR^{n}] *(2011 Pre)*



The major products (A) and (C) are respectively

a. $CH_2=C(CH_3)-CH_2-CH_3$ and $CH_3-C(Br)(CH_3)-CH_2-CH_3$

b. $CH_2=C(CH_3)-CH_2-CH_3$ and $CH_3-CH(Br)-CH(CH_3)-CH_3$

c. $CH_3-C(CH_3)=CH-CH_3$ and $CH_3-C(Br)(CH_3)-CH_2-CH_3$

d. $CH_3-C(CH_3)=CH-CH_3$ and $CH_3-CH(Br)-CH(CH_3)-CH_3$

35. Which of the following compounds will exhibit *cis-trans* (geometrical) isomerism? *(2009)*

a. Butanol b. 2-Butyne
c. 2-Butenol d. 2-Butene

36. $H_3C-CH(CH_3)-CH=CH_2 + HBr \longrightarrow A$

A (predominantly) is: *(2008)*

a. $CH_3-CH(CH_3)-CH(Br)-CH_2$ b. $CH_3-CH(CH_3)-CH_2-CH_2Br$

c. $CH_3-C(Br)(CH_3)-CH_2CH_3$ d. $CH_3-CH(Br)-CH(CH_3)-CH_3$

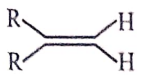
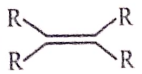
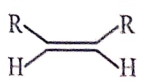
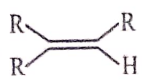
37. How many stereoisomers does the following molecule have? $CH_3CH=CHCH_2CHBrCH_3$ *(2008)*

a. 2 b. 4
c. 6 d. 8

38. Which of the compounds with molecular formula C_5H_{10} yields acetone on ozonolysis? *(2007)*

a. 3-methyl-1-butene b. cyclopentane
c. 2-methyl-1-butene d. 2-methyl-2-butene

39. Which one of the following alkenes will react faster with H_2 under catalytic hydrogenation conditions? *(2005)*

a. 
b. 
c. 
d. 

40. Which one of the following pairs represents stereoisomerism? *(2005)*

a. Chain isomerism and rotational isomerism
b. Structural isomerism and geometric isomerism
c. Linkage isomerism and geometric isomerism
d. Optical isomerism and geometric isomerism

41. Reaction of HBr with propene in the presence of peroxide gives:- *(2004)*

a. 3-bromo propane b. Allyl bromide
c. n-propyl bromide d. Isopropyl bromide

42. The compound $CH_3-C(CH_3)=CH-CH_3$ on reaction with $NaIO_4$ in the presence of $KMnO_4$ gives: *(2003)*

a. CH_3COCH_3 b. $CH_3COCH_3 + CH_3COOH$
c. $CH_3CHO + CO_2$ d. $CH_3COCH_3 + CH_3CHO$

43. In preparation of alkene from alcohol using Al_2O_3 which is effective factor? *(2001)*

a. Porousity of Al_2O_3 b. Temperature
c. Concentration d. Surface area of Al_2O_3

44. Which reagent converts propene to 1-propanol? *(2000)*

a. H_2O, H_2SO_4
b. B_2H_6, H_2O_2, OH^-
c. $Hg(OAc)_2$, $NaBH_4/H_2O$
d. Aq. KOH

45. Correct order of stability is: *(2000)*

a. 1-butene > Trans- 2-butene > Cis- 2-butene
b. Trans- 2-butene > 1-butene > Cis- 2-butene
c. Trans- 2-butene > Cis- 2-butene > 1-butene
d. Cis-2 butene > Trans- 2-butene > 1-butene

46. 2-butene shows geometrical isomerism due to: *(2000)*

a. Restricted rotation about double bond
b. Free rotation about double bond
c. Free rotation about single bond
d. Chiral carbon

47. Which is most stable? *(2000)*

a. 1-Butane b. *cis*-2-Butene
c. *trans*-2-Butene d. All have same stability

48. In a reaction:

$$CH_2=CH_2 \xrightarrow[\text{acid}]{\text{Hypochlorous}} M \xrightarrow{R} \begin{matrix}CH_2OH\\|\\CH_2OH\end{matrix}$$

where M = Molecule and R = Reagent. M and R are: *(1997)*

a. CH_3CH_2OH and HCl
b. $CH_2=CH_2$ and heat
c. CH_3CH_2Cl and NaOH
d. CH_2Cl-CH_2OH and aq. $NaHCO_3$

49. The reaction,
$CH_2 = CH - CH_3 + HBr \rightarrow CH_3CHBr - CH_3$ is *(1996)*

a. Electrophilic substitution
b. Free radical addition
c. Nucleophilic addition
d. Electrophilic addition

50. Which of the following has zero dipole moment? *(1996)*

a. 1 -Butene
b. 2-Methyl-1-propene
c. *cis*-2-Butene
d. *trans*-2-Butene

51. The alkene, $R - CH = CH_2$ reacts readily with B_2H_6 and the product on oxidation with alkaline hydrogen peroxides produces: *(1995)*

a. $R-\underset{\underset{CH_3}{|}}{C}=O$
b. $R-\underset{\underset{OH}{|}}{CH}-\underset{\underset{OH}{|}}{CH_2}$
c. $R-CH_2-CHO$
d. $R-CH_2-CH_2-OH$

52. One of the following which does not observe the anti-Markonikov's addition of HBr, is: *(1994)*

a. pent-2-ene
b. propene
c. but-2-ene
d. but-1-ene

53. When hydrochloric acid gas is treated with propene in presence of benzoyl peroxide, it gives: (1993)

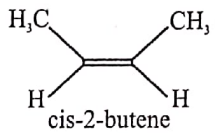
a. 2-chloropropane
b. allyl chloride
c. no reaction
d. *n*-propyl chloride

Alkynes

54. The number of sigma (s) and pi (p) bonds in pent-2-en-4-yne is *(2019)*

a. 10 s bonds and 3p bonds
b. 8 s bonds and 5p bonds
c. 11 s bonds and 2p bonds
d. 13 s bonds and no p bonds

55. The most suitable reagent for the following conversion, is: *(2019)*

$H_3C-C\equiv C-CH_3 \longrightarrow$  cis-2-butene

a. Na/liquid NH_3
b. H_2, Pd/C, quinoline
c. Zn/HCl
d. Hg^{2+}/H^+, H_2O

56. Predict the correct intermediate and product in the following reaction [**MR***] *(2017-Delhi)*

$H_3C-C\equiv CH \xrightarrow[HgSO_4]{H_2O,H_2SO_4}$ intermediate $\rightarrow$ product
(A) (B)

a. A: $H_3C-\underset{\underset{SO_4}{|}}{C}=CH_2$ B: $H_3C-\overset{\overset{O}{||}}{C}-CH_3$
b. A: $H_3C-\underset{\underset{OH}{|}}{C}=CH_2$ B: $H_3C-\overset{\overset{O}{||}}{C}-CH_3$
c. A: $H_3C-\underset{\underset{OH}{|}}{C}=CH_2$ B: $H_3C-\underset{\underset{SO_4}{|}}{C}=CH_2$
d. A: $H_3C-\underset{\underset{O}{|}}{C}-CH_3$ B: $H_3C-C\equiv CH$

57. Which one is the correct order of acidity? [**MR***] *(2017-Delhi)*

a. $CH_3-CH_3 > CH_2=CH_2 > CH_3-C\equiv CH > CH\equiv CH$
b. $CH_2=CH_2 > CH_3-CH=CH_2 > CH_3-C\equiv CH > CH\equiv CH$
c. $CH\equiv CH > CH_3-C\equiv CH > CH_2=CH_2 > CH_3-CH_3$
d. $CH\equiv CH > CH_2=CH_2 > CH_3-C\equiv CH > CH_3-CH_3$

58. In the reaction: *(2016-I)*

$H-C\equiv CH \xrightarrow[(2)\ CH_3CH_2Br]{(1)\ NaNH_2/liq.NH_3} X \xrightarrow[(2)\ CH_3CH_2Br]{(1)\ NaNH_2/liq.NH_3} Y$

a. X = 1-Butyne ; Y = 2-Hexyne
b. X = 1-Butyne ; Y = 3-Hexyne
c. X = 2-Butyne ; Y = 3-Hexyne
d. X = 2-Butyne ; Y = 2-Hexyne

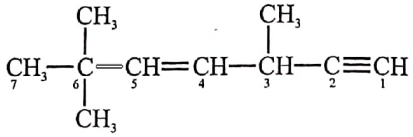
59. The pair of electron in the given carbanion, $CH_3C\equiv\overset{\ominus}{C}$, is present in which of the following orbitals? *(2016-I)*

a. sp
b. d^2sp
c. sp^3
d. sp^2

60. Which of the following reagents will be able to distinguish between 1-butyne and 2-butyne? *(2012 Mains)*

a. $NaNH_2$
b. HCl
c. O_2
d. Br_2

61. The state of hybridisation of C_2, C_3, C_5 and C_6 of the hydrocarbon,



is in the following sequence *(2009)*

a. sp^3, sp^2, sp^2 and sp
b. sp, sp^2, sp^2 and sp^3
c. sp, sp^2, sp^3 and sp^2
d. sp, sp^3, sp^2 and sp^3

62. Predict the product C obtained in the following reaction of 1-butyne: *(2007)*

$CH_3CH_2-C\equiv CH + HCl \rightarrow B \xrightarrow{HI} C$

a. $CH_3-CH_2-CH_2-\underset{\underset{Cl}{|}}{\overset{\overset{I}{|}}{C}}-H$
b. $CH_3-CH_2-\underset{\underset{I}{|}}{CH}-CH_2Cl$
c. $CH_3CH_2-\underset{\underset{Cl}{|}}{\overset{\overset{I}{|}}{C}}-CH_3$
d. $CH_3CH_2-\underset{\underset{Cl}{|}}{CH}-CH_2CH_2I$

63. Products of the following reaction:
$CH_3C{\equiv}CCH_2CH_3 \xrightarrow[(ii)\,Hydrolysis]{(i)\,O_3}$ .....are; [MR*] *(2005)*
a. $CH_3CHO + CH_3CH_2CHO$
b. $CH_3COOH + CH_3COCH_3$
c. $CH_3COOH + HOOCCH_2CH_3$
d. $CH_3COOH + CO_2$

64. When $CH_3CH_2CHCl_2$ is treated with $NaNH_2$, the product formed is: *(2002)*
a. $CH_3 - CH = CH_2$
b. $CH_3 - C \equiv CH$
c. $CH_3CH_2CH(NH_2)_2$
d. $CH_3CH_2CH(Cl)(NH_2)$

65. The cylindrical shape of an alkyne is due to: *(1997)*
a. Two sigma C – C and one π C – C bonds
b. One sigma C – C and two π C – C bonds
c. Three sigma C – C bonds
d. Three π C – C bonds

66. A compound is treated with $NaNH_2$ to give sodium salt. Identify the compound. *(1995)*
a. C_2H_2
b. C_6H_6
c. C_2H_6
d. C_2H_4

67. $R-CH_2-CCl_2-R \xrightarrow{Reagent} R-C\equiv C-R$
The reagent is: *(1993)*
a. Na
b. HCl in H_2O
c. KOH in C_2H_5OH
d. Zn in alcohol

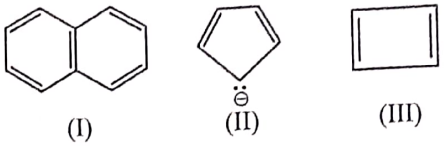
68. Reduction of 2-butyne with sodium in liquid ammonia gives predominantly: *(1993)*
a. *cis*-2-butene
b. no reaction
c. *trans*-2-butene
d. *n*-butane

69. Acetylenic hydrogens are acidic because: *(1989)*
a. Sigma electron density of C – H bond in acetylene is nearer to carbon; which has 50% *s*-character
b. Acetylene has only open hydrogen in each carbon
c. Acetylene contains least number of hydrogens among the possible hydrocarbons having two carbons
d. Acetylene belongs to the class of alkynes with molecular formula, C_nH_{2n-2}

70. Which is the most suitable reagent among the following to distinguish compound (3) from rest of the compounds? [MR*] *(1989)*
(1) $CH_3 - C \equiv C - CH_3$
(2) $CH_3 - CH_2 - CH_2 - CH_3$
(3) $CH_3 - CH_2C \equiv CH$
(4) $CH_3 - CH = CH_2$
a. Bromine in carbon tetrachloride
b. Bromine in acetic acid
c. Alk. $KMnO_4$
d. Ammonical silver nitrate

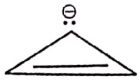
Aromatic Hydrocarbons

71. Consider the following compounds/species : [MR*] *(2023)*

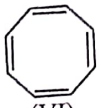

(I)

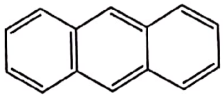
(II)

(III)

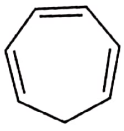
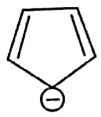
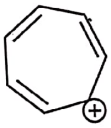

(IV)

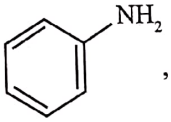
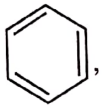
(V)

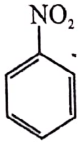
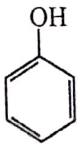
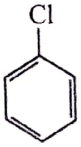

(VI)


(VII)

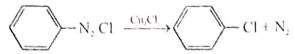
The number of compounds/species which obey Huckel's rule is _____.
a. 5
b. 4
c. 6
d. 2

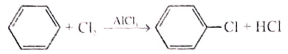
72. Which compound amongst the following is **not an aromatic** compound? *(2022)*
a. 
b. 
c. 
d.

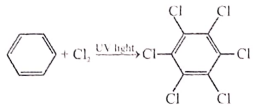
73. Which of the following is **suitable** to synthesize chlorobenzene? *(2022)*
a.  , HCl Heating
b. Benzene, Cl_2, anhydrous $FeCl_3$
c. Phenol, $NaNO_2$, HCl, CuCl
d.  , HCl

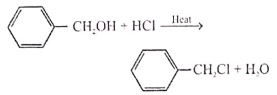
74. Which of the following compound is most reactive in electrophilic aromatic substitution? *(2020-Covid)*
a. 
b.
c. 
d. 

75. Among the following, the reaction that proceeds through an electrophilic substitution, is: *(2019)*

a. 

b. 

c. 

d. 

76. The compound C_7H_8 undergoes the following reactions: *(2018)*

$$C_7H_8 \xrightarrow{3Cl_2/\Delta} A \xrightarrow{Br_2/Fe} B \xrightarrow{Zn/HCl} C$$

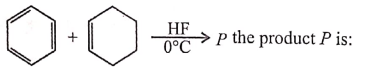
The product 'C' is

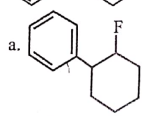
a. m-bromotoluene
b. o-bromotoluene
c. p-bromotoluene
d. 3-bromo-2,4,6-trichlorotoluene

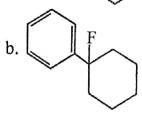
77. Which of the following can be used as the halide component for Friedel-Crafts reaction ? *(2016 - II)*

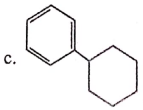
a. Chloroethene
b. Isopropyl chloride
c. Chlorobenzene
d. Bromobenzene

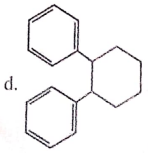
78. In the given reaction,

 *P* the product *P* is: *(2016 - II)*

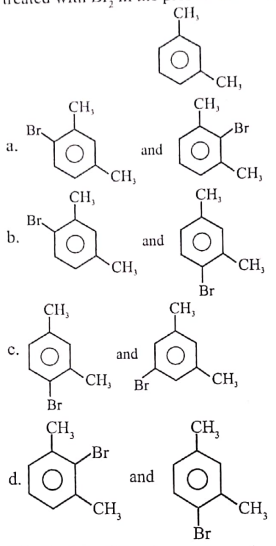
a. 

b. 

c. 

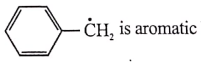
d. 

79. What products are formed when the following compound is treated with Br_2 in the presence of $FeBr_3$? *(2014)*



80. Which of the following compounds will not undergo Friedel-Craft reaction easily? *(2013)*

a. Cumene
b. Xylene
c. Nitrobenzene
d. Toluene

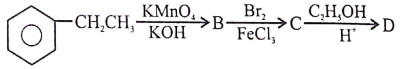
81. The radical,  is aromatic because it has: **[MR*]** *(2013)*

a. 6 p-orbitals and 6 unpaired electrons
b. 7 p-orbitals and 6 unpaired electrons
c. 7 p-orbitals and 7 unpaired electrons
d. 6 p-orbitals and 7 unpaired electrons

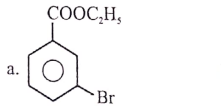
82. Among the following compounds, the one that is most reactive towards electrophilic nitration is *(2012, 1992)*

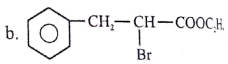
a. benzoic acid
b. nitrobenzene
c. toluene
d. benzene

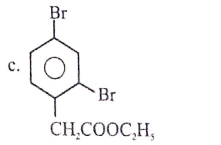
83. In a set of reactions, ethyl benzene yielded a product D.

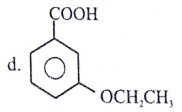


D would be *(2010 Pre)*

a. 

b. 

c. 

d. 

84. The reaction of and reaction in

a. X = Benzal
b. X = m-chlo
c. X = o- and
d. X = Benzyl

85. Nitrobenzene mixture of cor acid acts as a

a. Acid
c. Catalyst

86. Benzene reac $AlCl_3$ to form

a. Chlorober
c. Xylene

87. Using anhyd reactions pro

a. $CH_3 - CH$
c. $H_3C - CH$

88. Which one reaction?

a.

b.

c.

d. CH_3CH

89. The corre substitutic nitrobenz

a. III > II
c. I < II

90. Increasin compoun

(I)

a. IV <
c. I < I

84. The reaction of toluene with Cl_2 in presence of $FeCl_3$ gives X and reaction in presence of light gives Y. Thus, X and Y are: [MR*] *(2010 Pre)*

a. X = Benzal chloride, Y = o-chlorotoluene
b. X = m-chlorotoluene, Y = p-chlorotoluene
c. X = o- and p-chlorotoluene, Y = Trichloromethyl benzene
d. X = Benzyl chloride, Y = m-chlorotoluene

85. Nitrobenzene can be prepared from benzene by using a mixture of conc. HNO_3 and conc. H_2SO_4 in the mixture, nitric acid acts as a / an: *(2009)*

a. Acid b. Base
c. Catalyst d. Reducing agent

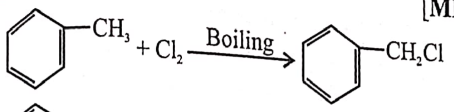
86. Benzene reacts with CH_3Cl in the presence of anhydrous $AlCl_3$ to form: *(2009)*

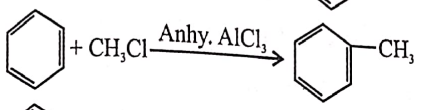
a. Chlorobenzene b. Benzylchloride
c. Xylene d. Toluene

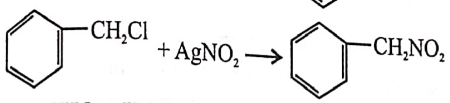
87. Using anhydrous $AlCl_3$ as catalyst, which one of the following reactions produces ethylbenzene (PhEt)? *(2004)*

a. $CH_3-CH=CH_2+C_6H_6$ b. $H_2C=CH_2+C_6H_6$
c. $H_3C-CH_3+C_6H_6$ d. $H_3C-CH_2OH+C_6H_6$

88. Which one of the following is a free-radical substitution reaction? [MR*] *(2003)*

a. 

b. 

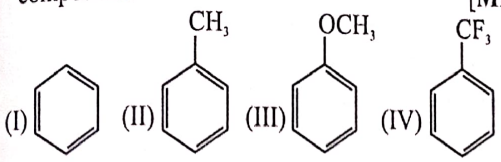
c. 

d. $CH_3CHO + HCN \rightarrow CH_3CH(OH)CN$

89. The correct order of reactivity towards the electrophilic substitution of the compounds aniline (I), benzene (II) and nitrobenzene (III) is: *(2003)*

a. III > II > I b. II > III > I
c. I < II > III d. I > II > III

90. Increasing order of electrophilic substitution for following compounds: [MR*] *(2000)*

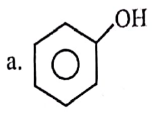


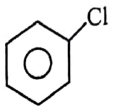
a. IV < I < II < III b. III < II < I < IV
c. I < IV < III < II d. II < III < I < IV

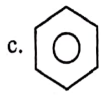
91. In Friedel craft reaction, toluene can be prepared by: *(2000)*

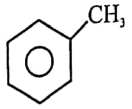
a. $C_6H_6 + CH_3Cl$ b. $C_6H_5Cl + CH_4$
c. $C_6H_6 + CH_2Cl_2$ d. $C_6H_6 + CH_3COCl$

92. Which of the following compounds will be most easily attacked by an electrophile? *(1999, 1998)*

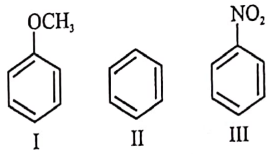
a. 

b. 

c. 

d. 

93. Among the following compounds (I-III), the correct reaction with electrophile is: *(1997)*



a. I > II > III b. I = II > III
c. II > III > I d. III < I < II

94. Electrophile in the case of chlorination of benzene in the presence of $FeCl_3$ is: *(1996)*

a. Cl b. $FeCl_3$
c. Cl^+ d. Cl^-

95. The reactive species in the nitration of benzene is: *(1994)*

a. NO_3 b. HNO_3
c. NO_2^+ d. NO_2^-

96. Which is the correct symbol relating the two Kekule structures of benzene? *(1993)*

a. $\rightleftharpoons$ b. $\longrightarrow$
c. $\equiv$ d. $\longleftrightarrow$

97. Select the true statement about benzene amongst the following: *(1992)*

a. Because of unsaturation benzene easily undergoes addition
b. There are two types of C – C bonds in benzene molecule
c. There is cyclic delocalisation of π-electrons in benzene
d. Monosubstitution of benzene gives three isomeric products

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Answer Key

1. (c)	2. (a)	3. (c)	4. (b)	5. (b)	6. (c)	7. (a)	8. (a)	9. (b)	10. (d)
11. (c)	12. (c)	13. (c)	14. (c)	15. (c)	16. (b)	17. (d)	18. (d)	19. (d)	20. (b)
21. (d)	22. (b)	23. (c)	24. (c)	25. (d)	26. (a)	27. (a)	28. (c)	29. (a)	30. (d)
31. (d)	32. (a)	33. (a)	34. (c)	35. (d)	36. (c)	37. (b)	38. (d)	39. (c)	40. (d)
41. (c)	42. (b)	43. (b)	44. (b)	45. (c)	46. (a)	47. (c)	48. (d)	49. (d)	50. (d)
51. (d)	52. (c)	53. (a)	54. (a)	55. (b)	56. (b)	57. (c)	58. (b)	59. (a)	60. (a)
61. (d)	62. (c)	63. (c)	64. (b)	65. (b)	66. (a)	67. (c)	68. (c)	69. (a)	70. (d)
71. (b)	72. (a)	73. (b)	74. (c)	75. (b)	76. (a)	77. (b)	78. (c)	79. (b)	80. (c)
81. (a)	82. (c)	83. (a)	84. (c)	85. (b)	86. (d)	87. (b)	88. (a)	89. (d)	90. (a)
91. (a)	92. (a)	93. (a)	94. (c)	95. (c)	96. (d)	97. (c)			

Explanations

1. (c) Sodium ethanoate is CH_3COONa and given process is soda-lime decarboxylation.

$$CH_3COONa + NaOH \xrightarrow{CaO} CH_4 + Na_2CO_3$$

Methane is obtained having molar mass 16. Two moles would be 32 g.

2. (a) Boiling point of alkanes is directly proportional to molar mass and is inversely proportional to the branching.

Therefore, straight chain alkanes have more boiling point than those of branched alkanes.

Heptane has high molar mass and 2-methyl propane has low molar mass and is branched.

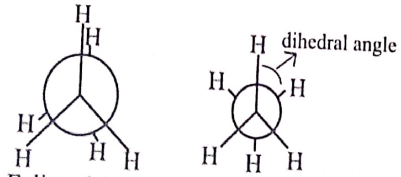
Hence, the decreasing order of boiling points of the given alkanes is:

heptane > hexane > 2-methyl butane > butane > 2-methyl propane

3. (c) Two conformers of ethane:

(1) Eclipsed

(2) Staggered



Eclipsed form Staggered form

In eclipsed form, dihedral angle = 0°

In staggered form, dihedral angle = 60°

Eclipsed conformer is least stable (with dihedral angle = 0°) and staggered conformer is most stable (with dihedral angle = 60°).

4. (b) Symmetrical alkane with even number of carbon atoms can be prepared by Wurtz reaction. In Wurtz reaction, alkyl halides are treated with sodium metal in dry ethereal solution giving higher alkanes.

$$R_1 - X + 2Na + X - R_1 \xrightarrow{\text{Dry ether}} R_1 - R_1 + 2NaX$$

If R_1 and R_2 are different, then mixture of alkanes may be obtained as

$$R_1 - X + 2Na + R_2 - X \xrightarrow{\text{Dry ether}} R_1 - R_1 + R_1 - R_2 + R_2 - R_2 + 2NaX$$

5. (b) Reaction of methane with Br_2 in the presence of light is a free radical substitution reaction.

$$\cdot Br \overset{\curvearrowleft}{-} \overset{\curvearrowright}{Br} \xrightarrow{h\nu} 2\dot{B}r$$

$$\cdot CH_3 \overset{\curvearrowleft}{-} \overset{\curvearrowright}{H} \xrightarrow{h\nu} \dot{C}H_3 + \dot{H}$$

$$\cdot CH_3 + \dot{B}r \longrightarrow CH_3 - Br$$

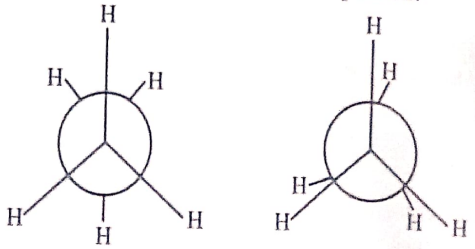
6. (c) Wurtz reaction gives symmetrical alkane with even no. of carbon atoms and since hydrocarbon containing less than four carbon atoms need to be obtained, therefore, the hydrocarbon A would be CH_4. The reaction takes place as:

$$CH_4 \xrightarrow[\text{substitution reaction}]{Br_2/h\nu} CH_3Br \xrightarrow[\text{Wurtz reaction}]{\text{Na/dry ether}} CH_3 - CH_3$$

7. (a) With respect to the conformers of ethane, both bond length and bond angles remain same.

Electron distribution of the sigma molecular orbital is symmetrical around the internuclear axis of C–C single bond.

8. (a) The correct statement is that staggered configuration of any molecule will always be more stable than eclipsed form because in staggered configuration, the atom attached are far apart from each other & exhibits less torsional strain and the bond pair electrons suffers less repulsion.

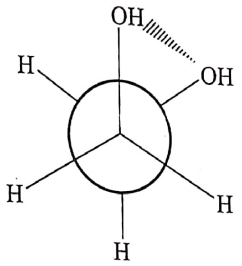


Staggered Newmann Eclipsed Newmann

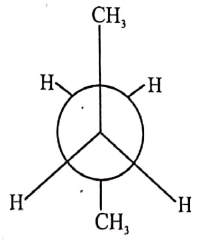
9. (b) Isomers are the compounds that have same structural formula but different structures.
For C_3H_9N, the total possible isomers are

1. $CH_3-CH_2-CH_2-NH_2$
2. $CH_3-\underset{\displaystyle NH_2}{\underset{|}{CH}}-CH_3$
3. $CH_3-CH_2-\underset{\displaystyle H}{\underset{|}{N}}-CH_3$
4. $\underset{\displaystyle CH_3}{\underset{|}{\overset{\displaystyle CH_3}{\overset{|}{N}}}}-CH_3$

10. (d) The conformer given in the option (d) is the gauche conformer and it is more stable as it involves intermolecular H-bonding as shown below:

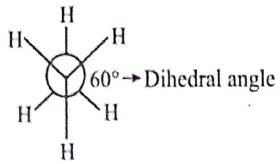


11. (c) The anti-staggered form of n-butane is the most stable form with least energy, because the bulky group $-CH_3$ are most far apart, distant from each other & the bonds are at greater angles from each other, thus constituting minimum repulsion in the molecule.



12. (c) Liquid hydrocarbons get converted to gaseous hydrocarbons by a process called cracking, where high molecular weight organic compounds break down into small chains upon heating.

13. (c) The staggered form of ethane has the following structure and the dihedral angle is 60°, which means 'H' atoms are at an angle of 60° to each other.

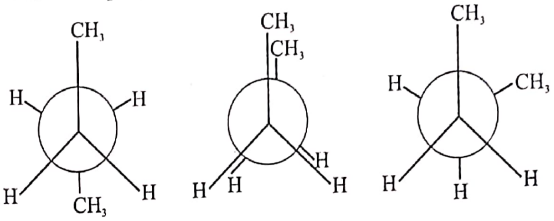


14. (c) When an aqueous solution of sodium or potassium salt of carboxylic acid is electrolysed, then an alkane containing even number of carbon atoms is formed at the anode. The reaction occurs as:

$$RCOOK \xrightarrow{\text{Electrolysis}} RH + CO_2 + KOH$$

15. (c) The branching of chain increases the octane number of a fuel. High octane number means better fuel. Hence, branched hydrocarbons are more desirable in the commercial gasolines.

16. (b) $CH_3CH_2CH_2CH_3$ - *n*-butane
Newmann projection for *n*-butane is



staggered eclipsed skew

The staggered conformation has minimum repulsion between the hydrogen atoms attached tetrahedrally to the two carbon atoms. Thus, it is the most stable conformation.

17. (d) The reactivity of H-atom depends upon the stability of free radicals which follows the order: 3° > 2° > 1°. Therefore, reactivity of H-atom also follows the some order, that is, tertiary > secondary > primary

18. (d) 3, 4-dimethyhex-3-ene will show geometrical isomerism.

$$CH_3\text{–}\overset{\displaystyle CH_3}{\overset{|}{H_2C}}\text{–}\overset{\displaystyle sp^2}{C} = \overset{\displaystyle sp^2}{C}\text{–}\overset{\displaystyle CH_3}{\overset{|}{CH_2}}\text{–}CH_3$$

19. (d)

a. $\underset{\displaystyle X}{\underset{|}{CH_2}}-\underset{\displaystyle X}{\underset{|}{CH_2}} \xrightarrow[\text{Metal}]{\text{Zn}} CH_2 = CH_2$
(Vic dihalides)

b. $R-C\equiv C-R \xrightarrow[\text{Liq } NH_3]{\text{Na}} \underset{\displaystyle H}{\overset{\displaystyle R}{\diagdown}}C=C\underset{\displaystyle R}{\overset{\displaystyle H}{\diagup}}$
(Alkyne)

c. $CH_3-CH_2-\underset{\displaystyle Cl}{\underset{|}{CH}}-CH_3 \xrightarrow{\text{alc.KOH}} CH_3-CH=CH-CH_3 + CH_3-CH_2-CH=CH_2$

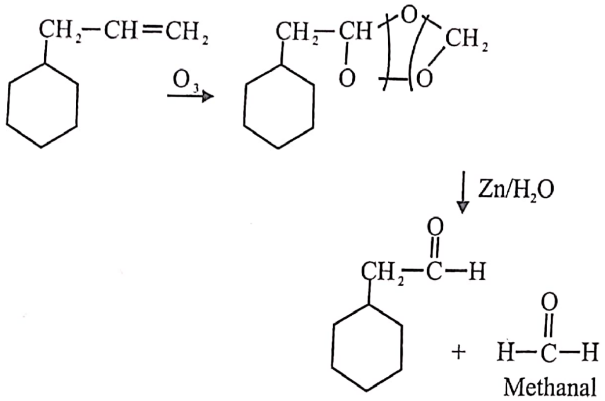
d. $R-Cl \xrightarrow{\text{aq KOH}} R-OH$

20. (b) $CH_3-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH=CH_2 \xrightarrow[\text{(i) Zn + } H_2O]{\text{(i) } O_3} H_3C-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CHO$
3-Methylbut-1-ene
2-Methylpropanal + H–CHO Formaldehyde

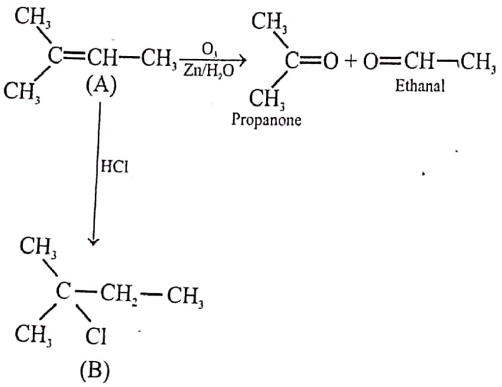
21. (d) In the presence of peroxide, addition of HBr to unsymmetrical alkenes take place according to Antimarkovnikov's rule. According to which, negative part of the adding molecule gets attached to that carbon atom which posess more number of H-atom.

$$\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\diagup}}CH-CH=CH_2 + HBr \xrightarrow{(C_6H_5CO)_2O_2} \underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\diagup}}CH-CH_2-CH_2-Br$$

22. (b) During ozonolysis, an alkene is oxidised in such a way that C = C bond is broken and each C gets a new bond –C = O. Here, methanal can only be formed if the double bond is with a terminal C-atom, so that after reaction, it gets converted into $H_2C = O$. The reaction takes place as:



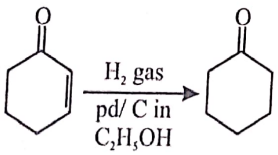
23. (c)



24. (c) Gaseous bromine reacts with alkenes to give allyl substituted alkyl halides via free radical mechanism. And reactivity depends on the stability of free radical which in propene is stabilised by the conjugation with π-bond as compared to ethene. Therefore, propene reacts readily. The reaction takes place as:

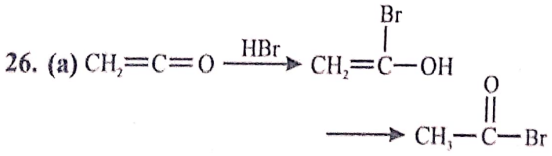
$$CH_3CH = CH_2 \xrightarrow{Br_2(g)} CH_3 - \underset{Br}{CH} - CH_2 - Br$$

25. (d)



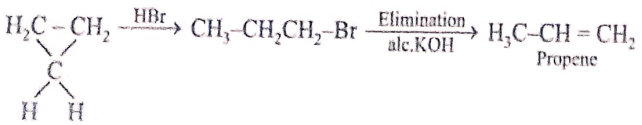
H_2 gas in pd/C causes simple reduction reaction and results in the formation of alkanes. It adds hydrogen to the double bond.

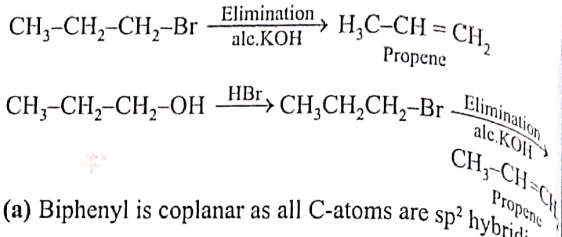
26. (a)



This reaction will not give propene

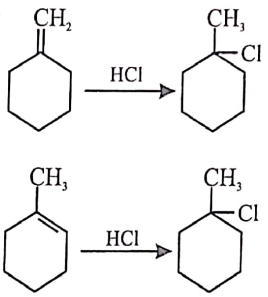
Whereas cyclopropane, $CH_3-CH_2-CH_2-Br$ & $CH_3-CH_2-CH_2-OH$ will give propene by elimination reaction. The reaction takes place as:





27. (a) Biphenyl is coplanar as all C-atoms are sp^2 hybridised.

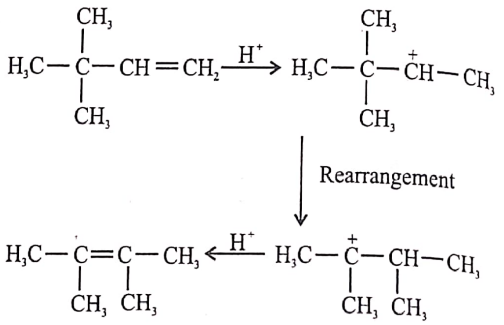
28. (c)



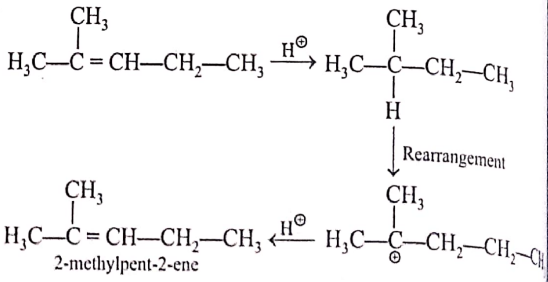
Markovnikov rule says that the halogen group goes to C with less number of H, in both the cases the same product will be formed.

29. (a)

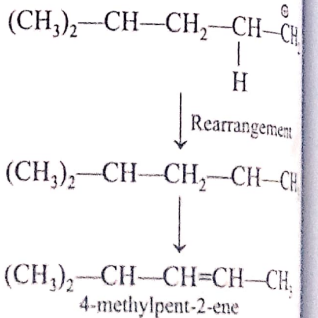
(a)



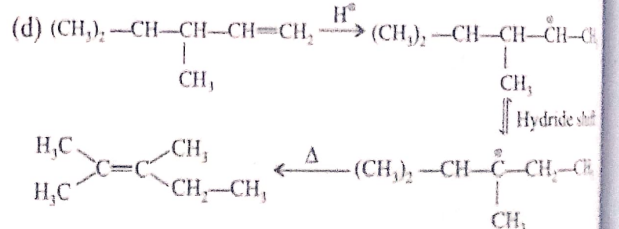
(b)

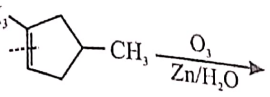


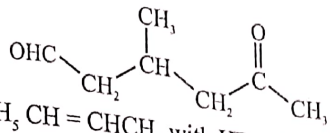
(c) $(CH_3)_2-CH-CH_2-CH=CH_2 \xrightarrow{H^\oplus}$



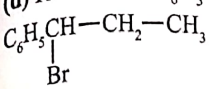
(d)



30. (d) 



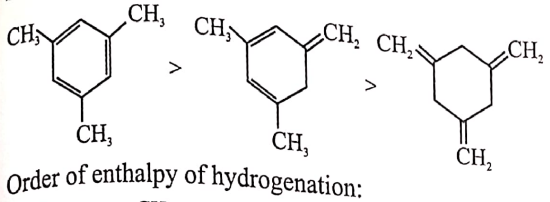
31. (d) Reaction of $C_6H_5CH=CHCH_3$ with HBr yields



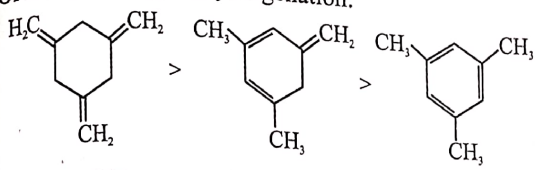
As benzoyl carbocation formed here will be most stable due to resonance.

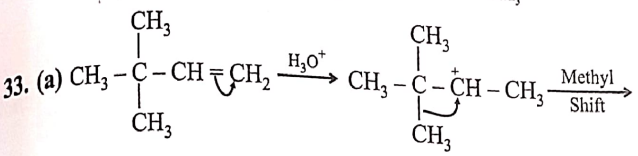
32. (a) Enthalpy of hydrogenation is inversely proportional to stability of alkenes.

Stability of alkenes:

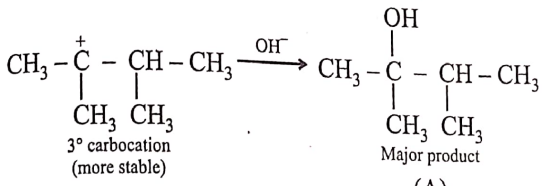


Order of enthalpy of hydrogenation:



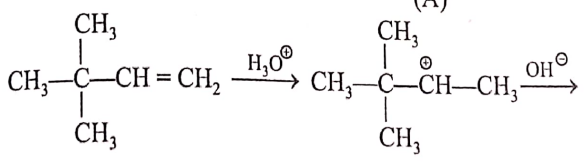
33. (a) 

2° carbocation (less stable)

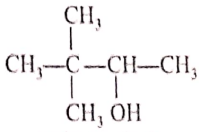


3° carbocation (more stable)

Major product (A)

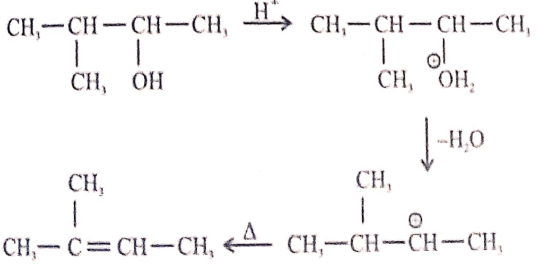


(2° carbocation less stable)

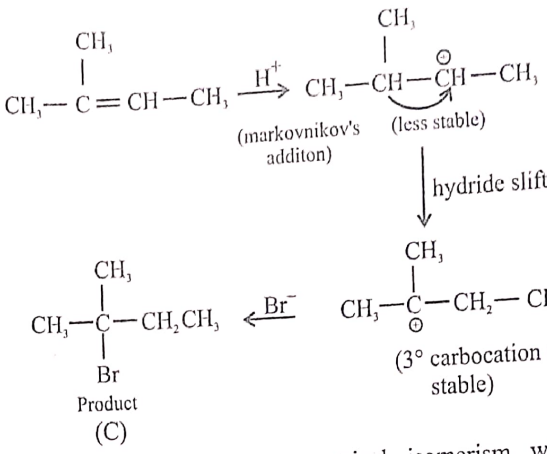


(minor product) (B)

34. (c)

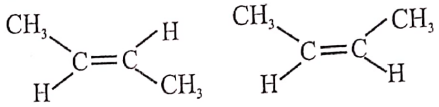


Product (A)

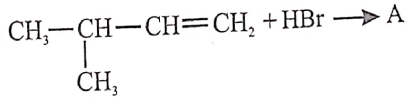


Product (C)

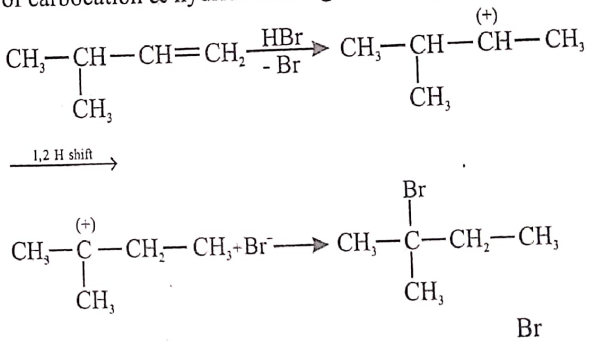
35. (d) 2-Butene exhibits geometrical isomerism with two structures cis & trans.



trans 2 butene cis-2-butene

36. (c) 

This is an electrophilic addition reaction, where rearrangement of carbocation & hydride shifting will take place.



37. (b) The structure of $CH_3—CH=CH—CH_2—\underset{*}{CH}—CH_3$ shows that it has two stereogenic centres. It is marked with astrick (*).

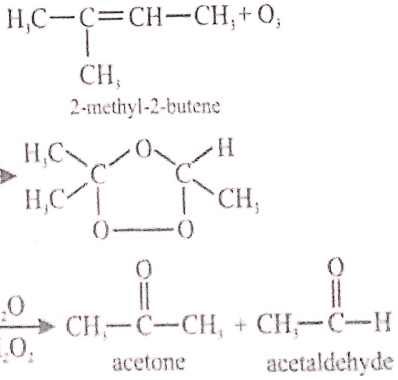
No. of stereoismers = 2^n

where, n = number of stereogentic centres

Hence, $2^n = 2^2 = 4$

Thus, 4 stereoisomers will be possible.

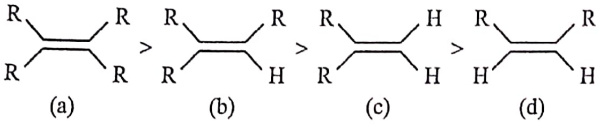
38. (d)



acetone acetaldehyde

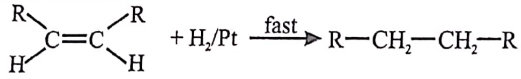
39. (c) Rate of Hydrogenation $\propto \frac{1}{\text{stability of alkene}}$

An alkene is considered more stable if it has more alkyl groups. Hence, correct order of stability is:



(a) (b) (c) (d)

Hence alkene which will react faster with H_2 is that which is most unstable.



40. (d) Optical and geometrical isomerism constitutes stereoisomerism.

41. (c) $CH_3 - CH = CH_2 + HBr$

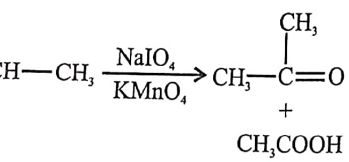
$\downarrow$ addition of HBr in the presence of H_2O_2

$CH_3 - CH_2 - CH_2 - Br$

n-propyl bromide

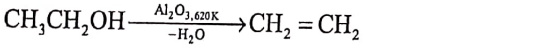
Here, anti-markovnikov's addition of HBr takes place.

42. (b)

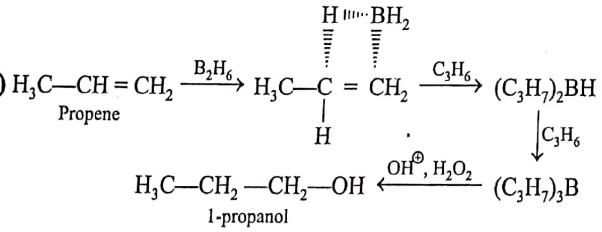


43. (b) Temperature is the effective factor for dehydration of alcohols by Al_2O_3, alcohols may be dehydrated to the corresponding olefin. The order of ease of dehydration is

3° alcohol > 2° alcohol > 1° alcohol.



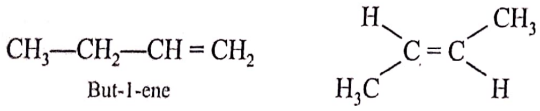
44. (b)



Propene

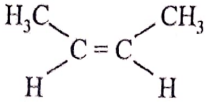
1-propanol

45. (c) As the number of alkyl groups around the double bond increases, the stability also increases.



But-1-ene

trans-But-2-ene



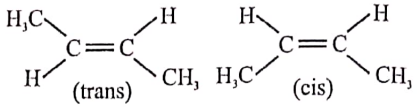
cis-But-2-ene

Thus, from the structures it can be seen But-1-ene has less alkyl groups, therefore, least stable.

Trans-But-2-ene is more stable than cis-But-2-ene, because bulky groups are present on the opposite side of the double bond, so lesser steric repulsion, and higher will be the stability.

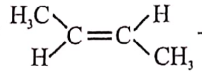
So, correct order is given by (c).

46. (a) Due to restricted rotation about double bond, 2-butene shows geometrical isomerism.



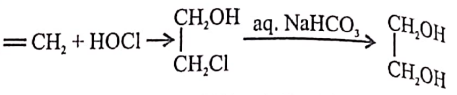
(trans) (cis)

47. (c)



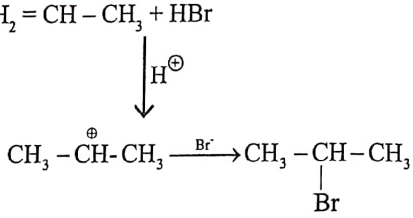
Most stable as the repulsion between 2 methyl group is least.

48. (d)

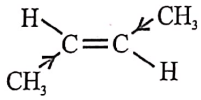


Therefore $M = ClH_2C{-}CH_2OH$ and $R = NaHCO_3$.

49. (d) In this reaction, HBr undergoes heterolytic fission as $HBr \rightarrow H^+ + Br^-$.



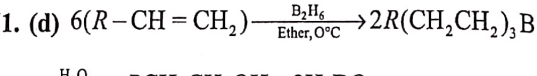
50. (d)



trans-2-butene

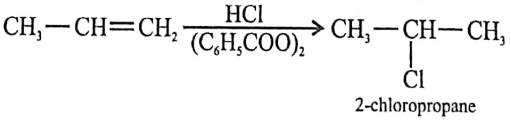
Both methyl group cancel each other. So net zero dipole moment exists.

51. (d)



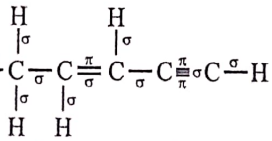
52. (c) In the case of but-2-ene ($CH_3 - CH = CH - CH_3$) both double bonded carbons are identical,. Therefore it does not observe the anti- Markovnikov's addition of HBr.

53. (a) Addition of HCl to propene even in the presence of benzoyl peroxide occurs according to Markovnikov's rule.



2-chloropropane

54. (a)

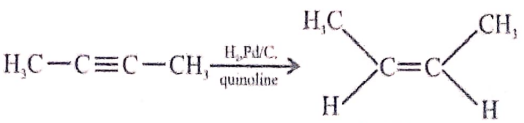


(Pent-2-en-4-yne)

Number of s bonds = 10

and number of p bonds = 3

55. (b) Alkynes are reduced to cis/trans alkenes with the help of Na/liq NH_3 and H_2, Pd/C in quinoline. Na/liq. NH_3 is used to form trans-alkene and H_2,Pd/C quinoline is used to form cis-alkene. Hence, cis-2-butene is formed in the following way:



cis-2-butene

56. **(b)** H_2SO_4 = Provide acidic medium.

$HgSO_4$ = Act as a solvent

The alkyne is converted into enol with the reagent $HgSO_4$ followed by acid hydrolysis. This reaction is oxymerurcuration..

$$H_3C-C\equiv C-H \xrightarrow[HgSO_4]{H_2O,\ H_2SO_4} CH_3-\underset{(A)}{\overset{OH}{\overset{|}{C}}}=CH_2$$

This enol in (A) is unstable, thus undergoes tautomerism.

$$CH_3-\overset{OH}{\overset{|}{C}}=CH_2 \xrightarrow{\text{Tautomerism}} CH_3-\overset{O}{\overset{\|}{C}}-CH_3$$

57. **(c)** Acidity $\propto$ stability of carbanion.

Carbanion is formed by the release of $H^{\oplus}$ ion and it's stability is directly related to E.N. The carbanion formed are

$CH_3-\overset{\ominus}{C}H_2$, $CH_2=\overset{\ominus}{C}H$, $CH_3-C\equiv\overset{\ominus}{C}$, $CH\equiv\overset{\ominus}{C}$

Now, $CH\equiv\overset{\ominus}{C}$ and $CH_3-C\equiv\overset{\ominus}{C}$, hybridisation is sp.

In $CH_2=\overset{\ominus}{C}H$, hybridisatiion is sp^2

In $CH_3=\overset{\ominus}{C}H_2$, hybridisation is sp^3

Electronegativity order: $sp > sp^2 > sp^3$

Stability of carbanion order :

$$CH\equiv\overset{\ominus}{C} > CH_3-C\equiv\overset{\ominus}{C} > CH_2=\overset{\ominus}{C}H > CH_3-\overset{\ominus}{C}H_2$$

Acidity order : $CH\equiv CH > CH_3-C\equiv CH > CH_2=CH_2 > CH_3-CH_3$

$CH_3-C\equiv CH$ will be less acidic than $CH\equiv CH$ because there is a CH_3 group attached to an sp-carbon atom which will destabilise the carbanion formed. Hence, it is less acidic.

58. **(b)** $CH\equiv CH \xrightarrow[NH_3]{NaNH_2} CH\equiv\overset{(-)}{C}-Na+CH_3-\overset{(+)}{CH_2}-Br$

$\downarrow$

$CH_3-CH_2-C\equiv CH$ (X) But-1-yne

$$CH_3-CH_2-C\equiv CH \xrightarrow[liq-NH_3]{NaNH_2} CH_3-CH_2-C\equiv\overset{(-)}{C}+\overset{(+)}{CH_3CH_2}-Br \rightarrow CH_3-CH_2-C\equiv C-CH_2-CH_3$$

Hex-3-yne (Y)

59. **(a)** We need to calculate the hybridisation, i.e.

$$\text{hybridisation} = \frac{\text{Number of } \sigma\text{-electrons}}{2}$$

$$= \frac{2+2(\text{from negative ion})}{2} = 2$$

Hence, its hybridisation would be sp. Thus, pair of electron will be present in sp-orbital.

60. **(a)** Terminal alkynes (1-butyne) react with $NaNH_2$ to form sodium acetylide and evolve hydrogen but 2-butyne does not.

61. **(d)** $\overset{7}{\underset{sp^3}{CH_3}}-\overset{6}{\underset{sp^3}{\overset{CH_3}{\overset{|}{C}}}}-\overset{5}{\underset{sp^2}{CH}}=\overset{4}{\underset{sp^2}{CH}}-\overset{3}{\underset{sp^3}{\overset{CH_3}{\overset{|}{CH}}}}-\overset{2}{\underset{sp}{C}}\equiv\overset{1}{\underset{sp}{CH}}$

62. **(c)** According to Markovnikov's rule, negative part of the adding molecule, goes to that olefinic carbon which has less number of C-atoms.

$$CH_3-CH_2-C\equiv CH + HCl \longrightarrow CH_3-CH_2-\overset{Cl}{\overset{|}{C}}=CH_2 \xrightarrow{HI} CH_3-CH_2-\overset{I}{\overset{|}{\underset{Cl}{\overset{|}{C}}}}-CH_3$$

63. **(c)** On ozonolysis, higher alkynes form diketones which are further oxidised to dicarboxylic acid.

$$CH_3C\equiv C-CH_2CH_3 + O_3 \longrightarrow CH_3-\underset{O-O}{\overset{O}{\overset{/\ \backslash}{C\ \ C}}}-CH_2CH_3 \xrightarrow{H_2O} CH_3C(=O)-C(=O)-CH_2CH_3 \xrightarrow{H_2O_2} CH_3COOH + CH_3CH_2COOH$$

64. **(b)** The reaction is double dehydrohalogenation in the presence of a strong base, $NaNH_2$.

$CH_3CH_2CHCl_2$

$\downarrow NaNH_2$

$CH_3C\equiv CH$

65. **(b)** In alkynes $C\equiv C$, one sigma and two π-bonds are present. Sigma bond is formed by sp-hybrid orbitals whereas π-bonds are formed by unhybridised orbitals. Therefore, it shows cylindrical shape.

66. **(a)** Alkynes react with strong bases like $NaNH_2$ to form sodium acetylide derivative known as acetylides.

$$H-C\equiv C-H + NaNH_2 \rightarrow H-C\equiv\overset{-}{C}-\overset{+}{N}a + 1/2\,H_2$$

67. **(c)** The reaction takes place as:

$$R-\overset{Cl}{\overset{|}{\underset{Cl}{\overset{|}{C}}}}-R \xrightarrow{KOH + C_2H_5OH} R-C\equiv C-R + 2HCl$$

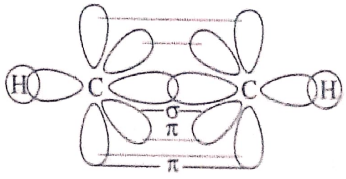
This reaction is an example of dehydrohalogenation.

68. **(c)** Reduction of non-terminal alkynes with Na in liq. NH_3 at 195 - 200 K gives *trans* alkene.

$$CH_3-C\equiv C-CH_3 \xrightarrow[195-200\ K]{\text{Na in liq. } NH_3} \underset{H}{\overset{CH_3}{\diagdown}}C=C\underset{CH_3}{\overset{H}{\diagup}}$$

trans-But-2-ene

(Birch reduction)

69. **(a)** 

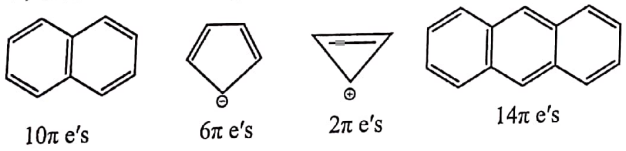
The formation of C – H bond in acetylene involves *sp*-hybridised carbon atom. Now, since *s*-electrons are closer to the nucleus than *p* electrons, the electrons present in a bond having more *s*-character will be more closer to the nucleus. In alkynes, *s*-character is 50%, the electrons constituting this bond are more strongly bonded by the carbon nucleus. Thus, acetylenic C-atom becomes more electronegative in comparison to sp^2, and hence the hydrogen atom present on carbon atom (≡ C – H) can be easily removed.

70. (d) All the three reagents except ammonical $AgNO_3$ reacts with 1, 2 and 4 compounds. The compound 3 possessing the terminal alkyne only reacts with ammoniacal $AgNO_3$ and thus can be distinguished from 1, 2 and 4 compounds.

71. (b) Acc. to Huckel rule, A compond/molecule is said to be aromatic if it have cyclic conjugate and $[4n + 2]\pi$ electron system

⇒ Molecule must be sp^2 hybridised

⇒ Molecule must be planar.



10π e's 6π e's 2π e's 14π e's

All these are aromatic species acc. to Huckel rule.

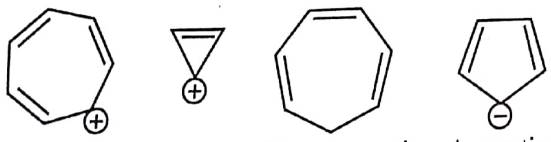
72. (a) Conditions for the compound to be aromatic-

(i) Planarity

(ii) Complete delocalisation of π electrons in the ring.

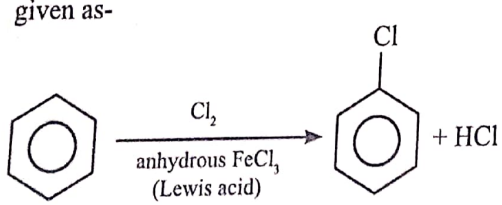
(iii) Presence of $(4n + 2)\pi$ electrons i.e., must follow Huckel rule.

In the given compounds only compound "a" is not aromatic because it contains sp^3 hybridised carbon which makes ring not planar & hence, does not show delocalisation. Also, compounds b,c and d are aromatic as they follow all the conditions of aromaticity.



Aromatic Aromatic Non-Aromatic Aromatic

73. (b) The suitable method for the synthesis of chlorobenzene is given as-

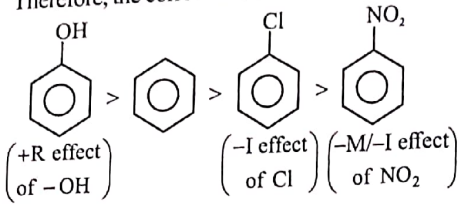


Benzene

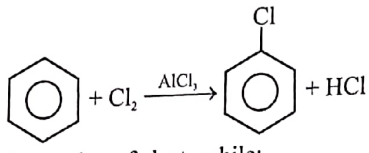
74. (c) Greater is the electron density on benzene ring, greater is the reactivity towards electrophilic aromatic substitution.

Electron withdrawing groups like NO_2,Cl decreases the electron density on benzene ring.

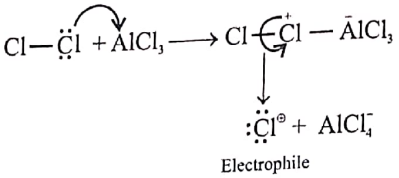
Phenol is more reactive than benzene towards electrophilic substitution reaction because the donation of the oxygen's lone pair into the ring system increases the electron density around the ring. Thus makes the ring much more reactive than benzene. Also, the –I effect of $-NO_2$ group is more than that of –Cl group, therefore, (d) is more reactive than (a). Therefore, the correct order of Electrophilic aromatic substitution is



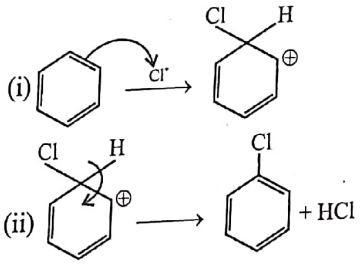
75. (b)



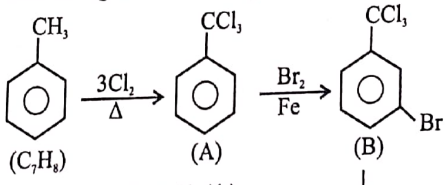
Generation of electrophile:



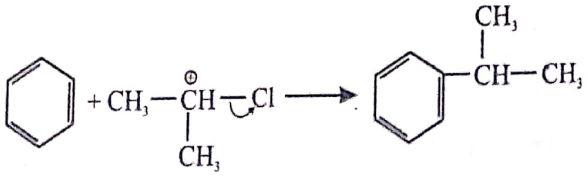
Electrophile



76. (a) In the first step, free radical substitution reaction of chlorine takes place and all the three H of $-CH_3$ side groups in toulene are replaced by the chlorine one by one and the product Benzochloride is obtained. Benzochloride in presence of Br_2/Fe gives an electrophilic substitution reaction. Br_2/Fe generates a free radical, Br. Which attacks on the meta position, hence, m-bromo benzochloride is obtaind. Now, in the last step, HCl being a polar protic solvent replaces the –Cl of side chain CCl_3 and changes it into $-CH_3$. Thus, C is m-bromotoulene.



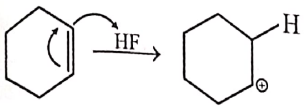
77. (b) In the case of iso-propyl chloride, lonepairs on chlorine reacts with lewis acid and gives 2° carbocation.



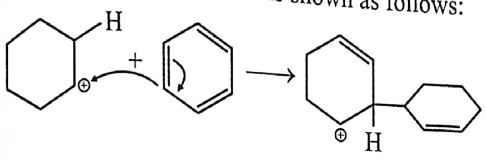
Iso-propyl chloride cumene

In chlorobenzene, bromobenzene or chloroethene, lone pair of electron on halogen atom are delocalised and attains the double bond character. So, all of these shows less reactivity with lewis acid.

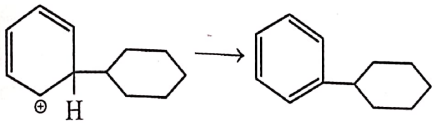
78. (c) Firstly, the cyclohexene reacts with acid hydrogen fluoride, where in, cyclohexene abstracts protons from the HF and forms a cation of cyclohexane as follows:

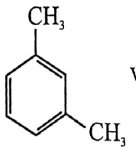


The benzene attacks on the cyclohexyl cation to form the cation again. The reaction is shown as follows:

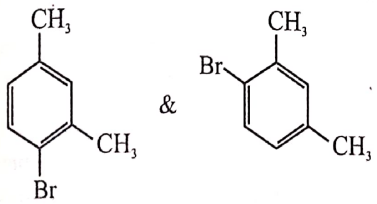


The positive charge is stabilised by the delocalis atom iin the benzene ring. The abstraction of hydrogen form the benzene ring gives the final product.

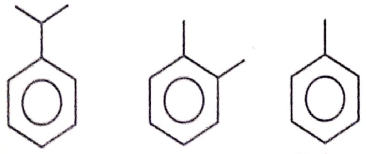


79. (b)  with $Br_2/FeBr_3$ shows Friedel's craft's reaction.

CH_3 group is an ortho & para directing group so, electron density will be more on ortho & para site. Hence, the products are:

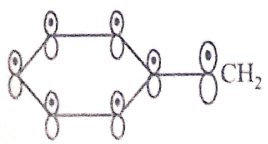


80. (c) $-NO_2$ on benzene is a strong deactivating agent & will not undergo Friedel-Craft's reaction easily as it will repel the incoming $E^{\oplus}$. While the remaining compounds given below are containing electron-donating groups, which increases e⁻ density on the ring, hence, can easily undergo Friedel-Craft's reaction.



Cumene Xylene Toulene

81. (a) Benzyl free radical is aromatic as it has 6 electrons present in the p-orbital of carbon atoms involved in the formation of the benzene ring.



According to Huckel's rule, for any compound to be aromatic. it must have $(4n + 2)\pi$-electrons, where, n = 0, 1, 2, 3, ..

$4n + 2 = 6$

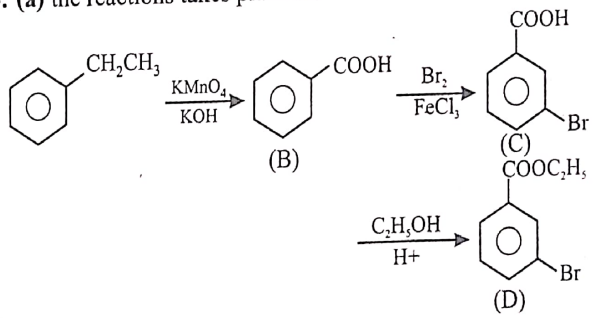
$4n = 4$

$\boxed{n = 1}$

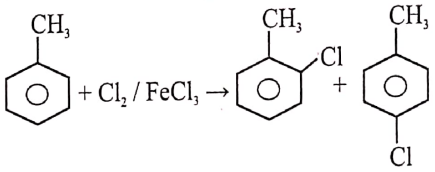
Since, the value of 'n' is an integer, therefore it is aromatic.

82. (c) As the +I effect increases, reactivity towards electrophilic reactions increase, and as –I or –M effect increases, reactivity towards electrophilic reactions decreases. Since, $-CH_3$ shows +I effect and COOH, NO_2 shows –I/–M effect, therefore toulene is the most reactive.

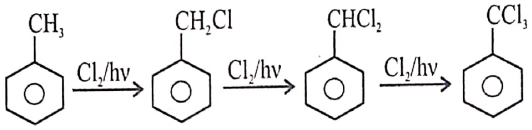
83. (a) the reactions takes place as:



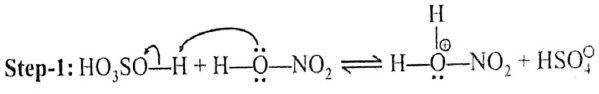
84. (c) In presence of Cl_2 in $FeCl_3$, the reaction takes place as:

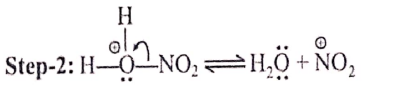


In presence of sunlight, the reaction takes place as:

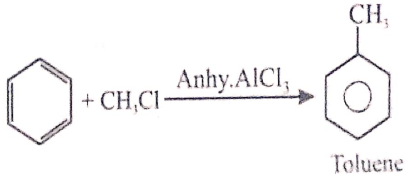


85. (b) Since, H_2SO_4 denotes its proton to HNO_3, therefore H_2SO_4 (sulphuric acid) behave as acid & HNO_3 (nitric acid) behave as a base. It occurs as:

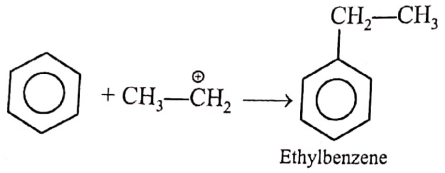




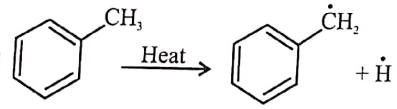
86. (d) $AlCl_3$ (anhy.) is a Lewis acid in the reaction & it helps in the formation of electrophile, $CH_3^{\oplus}$



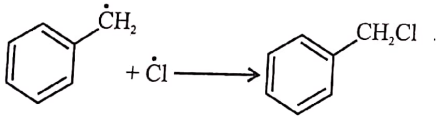
87. (b) $CH_2 = CH_2 \xrightarrow{AlCl_3/HCl} CH_3 - CH_2^{\oplus} + AlCl_4^{\ominus}$



88. (a)



$Cl_2 \xrightarrow[\text{sunlight}]{\text{Energy}} 2\dot{C}l$



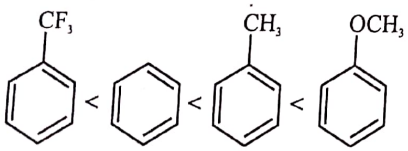
89. (d) Electrophilic substitution takes place fastest when the substrate is electron rich in nature.

In aniline, lone pair of electron on nitrogen are available for donation, making it electron rich.

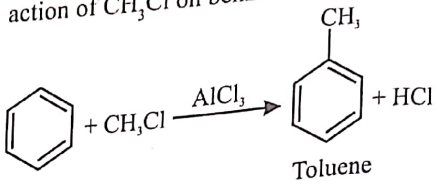
Whereas, in nitrobenzene, $-NO_2$ group is electron withdrawing making the substrate electron deficient. Hence, electrophilic substitution is slowest.

$\therefore$ The order becomes: I > II > III

90. (a) Due to –I effect of F atom, CF_3 in benzene ring deactivates the ring and does not favour eletrophilic substitution. While - CH_3 and - OCH_3 are (+I) group which favours electrophilic substitution in the benezene ring at 'ortho' and 'para' positions. The (+I) effect of $-OCH_3$ is more than $-CH_3$, therefore, the correct order for electrophilic substitution is



91. (a) In Friedel-crafts reaction, toluene is obtained by the action of CH_3Cl on benzene in presence of $AlCl_3$.



92. (a) Phenol consist of OH that is moderate electron donating group which is also an ortho-para directing group for electrophile in the ring. Hence, will be most easily attacked by the benzene ring as –OH group increases electron density in the ring.

93. (a) Electrophile will attack on that substrate, that is, electron rich. In 'III', $-NO_2$ group is an electron withdrawing group which decreases the electron density in the benzene ring, while, $-OCH_3$ group is an electron donating group which increases the electron density in the benzene ring, hence, electrophile will react readily on it. Thus, the correct order is I > II > III.

94. (c) $Cl_2 + FeCl_3 \rightarrow FeCl_4^- + Cl^+$, Hence, Cl^+ is an electrophile.

95. (c) Nitronium ion (NO_2^+) is an electrophile that actually attacks the benzene ring. And it is produced by transfer of proton from sulphuric acid to nitric acid in the following manner:

Step-1: $HO_3SO\text{—}H + H\text{—}O\text{—}NO_2 \rightleftharpoons H\text{—}\overset{\oplus}{O}\text{—}NO_2 + HSO_4^{\ominus}$ (H on O)

Step-2: $H\text{—}\overset{\oplus}{O}\text{—}NO_2 \rightleftharpoons H_2O + \overset{\oplus}{N}O_2$

(Protonated nitric acid) (Nitronium ion)

96. (d) Benzene shows kekule structures which are resonating structures and these structure are separated by a double headed arrow (↔).

97. (c) Due to resonance, all the C – C bonds in the benzene possess same nature and the resonating structures are obtained because of the delocalization of π-electrons.

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CHAPTER 1

Solutions

Expressing Concentration of Solutions

1. In one molal solution that contains 0.5 mole of a solute, there is *(2022)*
   a. 1000 g of solvent b. 500 mL of solvent
   c. 500 g of solvent d. 100 mL of solvent

2. Which of the following is dependent on temperature? [MR*] *(2017-Delhi)*
   a. Weight percentage b. Molality
   c. Molarity d. Mole fraction

3. What is the mole fraction of the solute in a 1.00 m aqueous solution? *(2015 Re)*
   a. 0.0177 b. 0.177
   c. 1.770 d. 0.0354

4. How many grams of concentrated nitric acid solution should be used to prepare 250 mL of 2.0 M HNO_3? The concentrated acid is 70% HNO_3. *(2013)*
   a. 70.0 g conc. HNO_3 b. 54.0 g conc. HNO_3
   c. 45.0 g conc. HNO_3 d. 90.0 g conc. HNO_3

5. Molecular weight of glucose is 180. A solution of glucose which contains 18 g per litre is: *(2012 Pre)*
   a. 2 molal b. 1 molal
   c. 0.1 molal d. 18 molal

6. To prepare a solution of concentration of 0.03 g ml^{-1} of $AgNO_3$, what amount of $AgNO_3$ should be added in 60 ml of solution: *(2011 Mains)*
   a. 1.8 b. 0.8
   c. 0.18 d. None of these

7. If 5.85 g of NaCl (molecular weight 58.5) is dissolved in water and the solution is made upto 0.5 litre, the molarity of the solution will be: *(2011 Mains)*
   a. 0.2 b. 0.4
   c. 1.0 d. 0.1

8. Mole fraction of the solute in a 1.00 molal aqueous solution is: [MR*] *(2011 Pre)*
   a. 1.7700 b. 0.1770
   c. 0.0177 d. 0.0344

9. Concentrated aqueous sulphuric acid is 98% H_2SO_4 by mass and has a density of 1.80 g mL^{-1}. Volume of acid required to make one litre of 0.1 MH_2SO_4 solution is: *(2007)*
   a. 16.65 mL b. 22.20 mL
   c. 5.55 mL d. 11.10 mL

10. 1 M and 2.5 litre NaOH solution mixed with another 0.5 M and 3 litre NaOH solution. Then find out molarity of resultant solution: *(2002)*
    a. 0.80 M b. 1.0 M
    c. 0.73 M d. 0.50 M

11. What is the molarity of H_2SO_4 solution, that has a density 1.84 g cc^{-1} at 35°C and contains 98% by weight? [MR*] *(1996)*
    a. 18.4 M b. 18 M
    c. 4.18 M d. 8.14 M

12. The concentration unit, independent of temperature, would be: *(1995, 1992)*
    a. Normality b. Weight volume percent
    c. Molality d. Molarity

13. How many grams of CH_3OH should be added to water to prepare 150 mL solution of 2 M CH_3OH? *(1994)*
    a. 9.6×10^3 b. 2.4×10^3
    c. 9.6 d. 2.4

Solubility

14. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R: *(2023)*

    Assertion A: Helium is used to dilute oxygen in diving apparatus.

    Reasons R: Helium has high solubility in O_2

    In the light of the above statements, choose the correct answer from the options given below:
    a. A is false but R is true.
    b. Both A and R are true and R is the correct explanation of A.
    c. Both A and R are true and R is NOT the correct explanation of A.
    d. A is true but R is false.

$CO_2 < CH_4 < Ar$

Vapour Pressure of Liquid Solutions

16. Which one is not correct mathematical equation for Dalton's Law of partial pressure? Here p = total pressure of gaseous mixture *(2022)*

a. $p_i = x_i p_i^\circ$, where x_i = mole fraction of i^{th} gas in gaseous mixture

p_i° = pressure of i^{th} gas in pure state

b. $p = p_1 + p_2 + p_3$

c. $p = n_1 \frac{RT}{V} + n_2 \frac{RT}{V} + n_3 \frac{RT}{V}$

d. $p_i = x_i p$, where p_i = partial pressure of i^{th} gas

x_i = mole fraction of i^{th} gas in gaseous mixture

17. The correct option for the value of vapour pressure of a solution at 45°C with benzene to octane in molar ratio 3 : 2 is: *(2021)*

[At 45°C vapour pressure of benzene is 280 mm Hg and that of octane is 420 mm Hg. Assume Ideal gas]

a. 168 mm of Hg
b. 336 mm of Hg
c. 350 mm of Hg
d. 160 mm of Hg

18. Which of the following statements about the composition of the vapour over an ideal 1 : 1 molar mixture of benzene and toluene is correct? Assume that the temperature is at 25°C.

(Given, vapour pressure data at 25°C, benzene = 12.8 kPa, toluene = 3.85 kPa) **[MR*]** *(2016-I)*

a. The vapour will contain equal amounts of benzene and toluene
b. Not enough information is given to make a prediction
c. The vapour will contain a higher percentage of benzene
d. The vapour will contain a higher percentage of toluene

19. Vapour pressure of chloroform ($CHCl_3$) and dichloromethane (CH_2Cl_2) at 25°C are 200 mm Hg and 41.5 mm Hg respectively. Vapour pressure of the solution obtained by mixing 25.5 g of $CHCl_3$ and 40 g of CH_2Cl_2 at the same temperature will be: (Molecular mass of $CHCl_3$ = 119.5 u and molecular mass of CH_2Cl_2 = 85 u): *(2012 Mains)*

a. 285.5 mm Hg
b. 173.9 mm Hg
c. 615.0 mm Hg
d. 90.3 mm Hg

20. A solution has a 1 : 4 mole ratio of pentane to hexane. The vapour pressure of the pure hydrocarbons at 20°C are 440 mm of Hg for pentane and 120 mm of Hg for hexane. The mole fraction of pentane in the vapour phase would be: *(2005)*

a. 0.178
b. 0.278
c. 0.378
d. 0.478

23. The vapour pressure of two liquids P and Q are 80 and 60 torr, respectively. The total vapour pressure of solution obtained by mixing 3 moles of P and 2 moles of Q would be: **[MR*]** *(2005)*

a. 144 torr
b. 288 torr
c. 14 torr
d. 72 torr

Ideal and Non-Ideal Solutions

24. The mixture which shows positive deviation from Raoult's law is: **[MR*]** *(2020)*

a. Benzene + Toluene
b. Acetone + Chloroform
c. Chloroethane + Bromoethane
d. Ethanol + Acetone

25. For an ideal solution, the correct option is : *(2019)*

a. $\Delta_{mix} S = 0$ at constant T and P
b. $\Delta_{mix} V \neq 0$ at constant T and P
c. $\Delta_{mix} H = 0$ at constant T and P
d. $\Delta_{mix} G = 0$ at constant T and P

26. The mixture that forms maximum boiling azeotrope is: *(2019)*

a. Water + Nitric acid
b. Ethanol + Water
c. Acetone + Carbon disulphide
d. Heptane + Octane

27. Which one of the following is incorrect for ideal solution? **[MR*]** *(2016 - II)*

a. $\Delta P = P_{obs} - P_{calculated\ by\ Raoult's\ law} = 0$
b. $\Delta G_{mix} = 0$
c. $\Delta H_{mix} = 0$
d. $\Delta U_{mix} = 0$

b. $\Delta H_{soln} = \Delta H_1 + \Delta H_2 - \Delta H_3$

c. $\Delta H_{soln} = \Delta H_1 - \Delta H_2 - \Delta H_3$

d. $\Delta H_{soln} = \Delta H_3 - \Delta H_1 - \Delta H_2$

31. A solution containing components A and B follows Raoult's law: *(2002)*

a. A – B attraction force is greater than A – A and B – B

b. A – B attraction force is less than A – A and B – B

c. A – B attraction force remains same as A – A and B – B

d. Volume of solution is different from sum of volume of solute and solvent

32. All form ideal solution except: *(1988)*

a. C_6H_6 and $C_6H_5CH_3$ b. C_2H_6 and C_2H_5I

c. C_6H_5Cl and C_6H_5Br d. C_2H_5I and C_2H_5OH

33. An ideal solution is formed when its components: $\Delta V_{mixing} = 0$ and $\Delta H_{mixing} = 0$ *(1988)*

a. Have no volume change on mixing

b. Have no enthalpy change on mixing

c. Have both the above characteristics

d. Have high solubility

Colligative Properties and Determination of Molar Mass

34. Which amongst the following aqueous solution of electrolytes will have minimum elevation in boiling point? Choose the **correct** option : *(2023-Manipur)*

a. 0.05 M NaCl b. 0.1 M KCl

c. 0.1 M $MgSO_4$ d. 1 M NaCl

35. The following solutions were prepared by dissolving 10 g of glucose ($C_6H_{12}O_6$) in 250 ml of water (P_1), 10 g of urea (CH_4N_2O) in 250 ml of water (P_2) and 10 g of sucrose ($C_{12}H_{22}O_{11}$) in 250 ml of water (P_3). The right option for the decreasing order of osmotic pressure of these solutions is: **[MR*]** *(2021)*

a. $P_1 > P_2 > P_3$ b. $P_2 > P_3 > P_1$

c. $P_3 > P_1 > P_2$ d. $P_2 > P_1 > P_3$

solute in 100 g water is 732 mm. If $K_b = 0.52$, the boiling point of this solution will be: *(2016 - I)*

a. 103° C b. 101° C

c. 100° C d. 102° C

40. Which of the following compounds can be used as antifreeze in automobile radiators? *(2012 Mains)*

a. Methyl alcohol b. Glycol

c. Nitrophenol d. Ethyl alcohol

41. 200 mL of an aqueous solution of a protein contains its 1.26 g. The osmotic pressure of this solution at 300 K is found to be 2.57×10^{-3} bar. The molar mass of protein will be: ($R = 0.083$ L bar $mol^{-1} K^{-1}$) **[MR*]** *(2011 Mains)*

a. 31011 g mol^{-1} b. 61038 g mol^{-1}

c. 51022 g mol^{-1} d. 122044 g mol^{-1}

42. A solution of sucrose (molar mass = 342 g mol^{-1}) has been prepared by dissolving 68.5 g of sucrose in 1000 g of water. The freezing point of the solution obtained will be: (K_f for water = 1.86 K kg mol^{-1}) *(2010 Pre)*

a. –0.570°C b. –0.372°C

c. –0.520°C d. +0.372°C

43. 1.00 g of a non-electrolyte solute (molar mass 250g mol^{-1}) was dissolved in 51.2 g of benzene. If the freezing point depression constant, K_f of benzene is 5.12 K kg mol^{-1}, the freezing point of benzene will be lowered by: *(2006)*

a. 0.4 K b. 0.8 K

c. 0.12 K d. 0.24 K

44. A solution containing 10 g dm^{-3} of urea (molecular mass = 60 g mol^{-1}). is isotonic with a 5% solution of a non-volatile solute. The molecular mass of this non-volatile solute is: *2006)*

a. 200 g mol^{-1} b. 300 g mol^{-1}

c. 400 g mol^{-1} d. 500 g mol^{-1}

45. During osmosis, flow of water through a semi-permeable membrane is: *(2006)*

a. From solution having higher concentration only

b. From both sides of semi-permeable membrane with equal flow rates

c. From both sides of semi-permeable membrane with unequal flow rates

d. From solution having lower concentration only

terms of osmotic pressure: *(2002)*

a. $M_2 = \left(\frac{m_2}{\pi}\right)VRT$ b. $M_2 = \left(\frac{m_2}{V}\right)\frac{RT}{\pi}$

c. $M_2 = \left(\frac{m_2}{V}\right)\pi RT$ d. $M_2 = \left(\frac{m_2}{V}\right)\frac{\pi}{RT}$

49. Pure water can be obtain from sea water by: *(2001)*

a. Centrifugation b. Plasmolysis

c. Reverse osmosis d. Sedimentation

50. From the colligative properties of solution which one is the best method for the determination of molecular weight of proteins and polymers: *(2000)*

a. Osmotic pressure

b. Lowering in Vapor pressure

c. Lowering in freezing point

d. Elevation in Boiling Point

51. If 0.15 g of solute, dissolved in 15 g of solvent, is boiled at a temperature higher by 0.216°C, than that of the pure solvent, the molecular weight of the substance is (molal elevation constant for the solvent is 2.16°C): *(1999)*

a. 1.01 b. 10

c. 10.1 d. 100

52. The vapour pressure of benzene at a certain temperature is 640 mm of Hg. A non-volatile and non-electrolyte solid, weighing 2.175 g is added to 39.08 g of benzene. If the vapour pressure of the solution is 600 mm of Hg, what is the molecular weight of solid substance? *(1999)*

a. 49.50 b. 59.60

c. 69.40 d. 79.82

53. A 5% solution of cane sugar (molecular weight = 342) is isotonic with 1% solution of a substance X. The molecular weight of X is: *(1998)*

a. 34.2 b. 171.2

c. 68.4 d. 136.8

54. The vapour pressure of a solvent decreased by10 mm in two columns of mercury when a non-volatile solute was added to the solvent. The mole fraction of the solute in the solution is 0.2. What should be the mole fraction of the solvent if the decrease in the vapour pressure is to be 20 mm of mercury? *(1998)*

a. 0.8 b. 0.6

c. 0.4 d. 0.2

58. If 0.1 M solution of glucose and 0.1 M solution of urea are placed on two sides of the semipermeable membrane to equal heights, then it will be correct to say that: *(1992)*

a. There will be no net movement across the membrane

b. Glucose will flow towards glucose solution

c. Urea will flow towards glucose solution

d. Water will flow from urea solution to glucose

59. Which one is a colligative property? *(1992)*

a. Boiling point b. Vapour pressure

c. Osmotic pressure d. Freezing point

60. Blood cells retain their normal shape in solution which are: *(1991)*

a. Hypotonic to blood b. Isotonic to blood

c. Hypertonic to blood d. Equinormal to blood

61. The relative lowering of the vapour pressure is equal to the ratio between the number of: *(1991)*

a. Solute molecules to the solvent molecules

b. Solute molecules to the total molecules in the solution

c. Solvent molecules to the total molecules in the solution

d. Solvent molecules to the total number of ions of the solute

Abnormal Molar Mass

62. The freezing point depression constant (K_f) of benzene is 5.12 K kg mol^{-1}. The freezing point depression for the solution of molality 0.078 m containing a non-electrolyte solute in benzene is (rounded off upto two decimal places) : **[MR*]** *(2020)*

a. 0.80 K b. 0.40 K

c. 0.60 K d. 0.20 K

63. The van't Hoff factor (i) for a dilute aqueous solution of the strong electrolyte barium hydroxide is: *(2016 - II)*

a. 2 b. 3

c. 0 d. 1

64. Which one of the following electrolytes has the same value of van't Hoff's factor (*i*) as that of $Al_2(SO_4)_3$ (if all are 100% ionised)? *(2015)*

a. $K_3[Fe(CN)_6]$ b. $Al(NO_3)_3$

c. $K_4[Fe(CN)_6]$ d. K_2SO_4

65. The boiling point of 0.2 mol kg^{-1} solution of X in water is greater than equimolal solution of Y in water. Which one of the following statements is true in this case? *(2015)*

a. Molecular mass of X is greater than the molecular mass of Y
b. Molecular mass of X is less than the molecular mass of Y
c. Y is undergoing dissociation in water while X undergoes no change
d. X is undergoing dissociation in water

66. Of the following 0.10 m aqueous solutions, which one will exhibit the largest freezing point depression? [**MR***] *(2014)*

a. $C_6H_{12}O_6$ b. $Al_2(SO_4)_3$
c. K_2SO_4 d. KCl

67. A 0.1 molal aqueous solution of a weak acid is 30% ionised. If K_f for water is 1.86°Cm^{-1}, the freezing point of the solution will be: *(2011 Mains)*

a. −0.36°C b. −0.24°C
c. −0.18°C d. −0.54°C

68. The freezing point depression constant for water is −1.86°Cm^{-1}. If 5.00 g Na_2SO_4 is dissolved in 45.0 g H_2O, the freezing point is changed by −3.82°C. Calculate the van't Hoff factor for Na_2SO_4: *(2011 Pre)*

a. 0.381 b. 2.05
c. 2.63 d. 3.11

69. The van't Hoff factor (i) for a compound which undergoes dissociation in one solvent and association in other solvent is respectively: *(2011 Pre)*

a. Greater than one and greater than one
b. Less than one and greater than one
c. Less than one and less than one
d. Greater than one and less than one

70. A 0.0020 m aqueous solution of an ionic compound $Co(NH_3)_5(NO_2)Cl$ freezes at −0.00732°C. Number of moles of ions which 1 mol of ionic compound produces on being dissolved in water will be: *(2009)*
(K_f = −1.86°C/m)

a. 3 b. 4
c. 1 d. 2

71. 0.5 M aqueous solution of a weak acid (HX) is 20% ionised. If K_f for water is 1.86 K kg mol^{-1}, the lowering in freezing point of the solution is: *(2007)*

a. 0.56 K b. 1.12 K
c. − 0.56 K d. − 1.12 K

72. Which of the following 0.10 m aqueous solution will have the lowest freezing point? *(1997)*

a. KI b. $C_{12}H_{22}O_{11}$
c. $Al_2(SO_4)_3$ d. $C_5H_{10}O_5$

73. At 25°C, the highest osmotic pressure is exhibited by 0.1 M solution of: *(1994)*

a. Glucose b. Urea
c. $CaCl_2$ d. KCl

74. Which of the following salt has the same value of van't Hoff factor *i* as that of $K_3[Fe(CN)_6]$? [**MR***] *(1994)*

a. Na_2SO_4 b. $Al(NO_3)_3$
c. $Al_2(SO_4)_3$ d. NaCl

75. Which of the following aqueous solution has minimum freezing point? [**MR***] *(1991)*

a. 0.01 m NaCl
b. 0.005 m C_2H_5OH
c. 0.005 m MgI_2
d. 0.005 m $MgSO_4$

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Answer Key

1. (c)	2. (c)	3. (a)	4. (c)	5. (c)	6. (a)	7. (a)	8. (c)	9. (c)	10. (c)
11. (a)	12. (c)	13. (c)	14. (d)	15. (b)	16. (a)	17. (b)	18. (c)	19. (d)	20. (a)
21. (a)	22. (d)	23. (d)	24. (d)	25. (c)	26. (a)	27. (b)	28. (a)	29. (b)	30. (a)
31. (c)	32. (d)	33. (c)	34. (a)	35. (d)	36. (d)	37. (b)	38. (a)	39. (b)	40. (b)
41. (b)	42. (b)	43. (a)	44. (b)	45. (d)	46. (d)	47. (a)	48. (b)	49. (c)	50. (a)
51. (d)	52. (c)	53. (c)	54. (b)	55. (c)	56. (a)	57. (a)	58. (a)	59. (c)	60. (b)
61. (b)	62. (b)	63. (b)	64. (c)	65. (d)	66. (b)	67. (b)	68. (c)	69. (d)	70. (d)
71. (b)	72. (c)	73. (c)	74. (b)	75. (a)					

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Explanations

1. (c) Molality $= \dfrac{\text{No. of moles of solute}}{\text{Weight of solvent (Kg)}}$

$1 = \dfrac{0.5}{\text{Weight of solvent (Kg)}}$

Weight of solvent (Kg) = 0.5 Kg = 500 g

2. (c) Molarity is defined as number of moles of solute dissolved in one liter (or one cubic decimeter) of solution.

Therefore, Molarity will depend upon temperature as volume of the solution will change with temperature.

3. (a) 1.00 m (or molal) aqueous solution means one mole of solute in 1 kg of water

1 kg of water corresponds to $\dfrac{1000}{18}$ moles i.e., 55.56 moles

Therefore, moles of solute = 1 moles of water

Total moles of components = 1 + 55.56

So, Mole fraction of solute $= \dfrac{\text{No. of moles of solute}}{\text{Total no. of moles of solution}}$

$$x_{\text{solute}} = \frac{1}{1+55.56} = 0.0177$$

4. (c) Molarity $= \dfrac{W \times 1000}{M \times V_{(mL)}}$

$2 = \dfrac{W}{63} \times \dfrac{1000}{250}$

$W = \dfrac{63}{2}$

but acid is 70% concentrated, Therefore,

Mass of acid $\times \dfrac{70}{100} = \dfrac{63}{2}$

Mass of acid = 45 g

5. (c) No. of moles of glucose $= \dfrac{\text{mass}}{\text{molar mass}} = \dfrac{18}{180} = 0.1$ mole

vol. of solvent (which is water) = 1 liter (given)

density of water $= \dfrac{1\text{kg}}{\text{L}}$

Therefore, mass = density × vol.

Mass $= \dfrac{1\text{kg}}{\text{L}} \times 1\text{ L} = 1\text{kg}$

Hence, Molality (m) $= \dfrac{0.1}{1} = 0.1$ m

6. (a) Concentration $= \dfrac{\text{moles}}{\text{volume}}$

$0.03\text{ g ml}^{-1} = \dfrac{\text{moles}}{60\text{ ml}}$

moles = 60 × 0.03 g = 1.8 g

Amount of $AgNO_3$ added in 60 mL of solution is 1.8 g.

7. (a) $M = \dfrac{w}{\text{Molecular Weight} \times \text{volume in litre}}$

$= \dfrac{5.85}{58.5 \times 0.5} = 0.2$ M

8. (c) Mole fraction of solution $= \dfrac{1}{56.55} = 0.0177$

9. (c) Molarity of H_2SO_4 solution

$= \dfrac{98 \times 1000}{98 \times 100} \times 1.80 = 18.0$

Suppose V mL of this H_2SO_4 is used to prepare 1 L of 0.1 M H_2SO_4

$\therefore V \times 18.0 = 1000 \times 0.1$

or $V = \dfrac{1000 \times 0.1}{18.0} = 5.55$ mL

10. (c) No. of moles of 2.5 L of 1 M NaOH = M × V

$= 1 \times 2.5 = 2.5$

No. of moles of 3.0 L of 0.5 M NaOH = 0.5 × 3.0 = 1.5

Total no. of moles of NaOH = 2.5 + 1.5 = 4.0

Total volume = 2.5 + 3.0 = 5.5 L

Molarity of resultant solution $= \dfrac{n}{V} = \dfrac{4.0}{5.5} = 0.73$ M

11. (a) Density of solution = 1.84 g cc^{-1}

Temperature (T) = 35°C and concentration of solute = 98% by weight.

We know that 98% H_2SO_4 by weight means 98 grams of H_2SO_4 is present in 100 grams of solution in water.

Therefore its weight is 98 and moles of H_2SO_4

$= \dfrac{\text{Weight of } H_2SO_4}{\text{Molecular weight}} = \dfrac{98}{98} = 1$

and volume of solution

$= \dfrac{\text{Mass}}{\text{Density}} = \dfrac{100}{1.84} = 54.35\text{ mL} = \dfrac{54.35}{1000}\text{ L}$

Therefore molarity of H_2SO_4

$= \dfrac{\text{Moles of } H_2SO_4}{\text{Volume (in litres)}} = \dfrac{1 \times 1000}{54.35} = 18.4\text{ M}$

12. (c) The molality involves weights of the solute and the solvent. Since the weight does not change with the temperature, therefore molality does not depend upon the temperature.

13. (c) Since the molecular mass of CH_3OH is 32, therefore quantity of CH_3OH to prepare 150 mL Solution of 2 M CH_3OH

We have to calculate no. of moles as,

n = M × V (in L)

$= 2 \times \dfrac{150}{1000} = 0.3$

Therefore, weight of CH_3OH is to be added = n × M.M.
$= 0.3 \times 32\ g = 9.6\ g$

14. (d) Helium is used as a diluent for oxygen in modern diving apparatus because of its very low solubility in blood.

15. (b) Solubility of a gas $\propto \frac{1}{K_H \text{ value}}$

i.e; Higher the value of K_H, lower will be the solubility.

$\therefore$ The order of solubility is:

$Ar < CO_2 < CH_4 < HCHO$

16. (a) According to Dalton's low of partial pressure:

Partial pressure of gas = Mole fraction of gas in gaseous mixture × Total pressure of gaseous mixture (not pure gas)

$p_1 = X_1 p$

$p_2 = X_2 p$

$p_3 = X_3 p$

Total pressure, $p = p_1 + p_2 + p_3$

17. (b) Given,

Vapour pressure of benzene (P_A) = 280 mm Hg

Vapour pressure of octanee (P_B) = 420 mm Hg

And,

Total molar ratio = 3 + 2 = 5

$\chi_{C_6H_6} = \frac{3}{5}, \chi_{C_8H_{18}} = \frac{2}{5}$

Now, Applying Raoult's law, $P_T = P_A x_A + P_B x_B$

$= \left(280 \times \frac{3}{5}\right) + \left(420 \times \frac{2}{5}\right) = \frac{840+840}{5} = 336 \text{ mm of Hg}$

18. (c) $P_{Benzene} = x_{Benzene} P^{\circ}_{Benzene}$

$P_{Toluene} = x_{Toluene} P^{\circ}_{Toluene}$

For an ideal 1 : 1 molar mixture of benzene and toluene.

$x_{Benzene} = \frac{1}{2};\ x_{Toluene} = \frac{1}{2}$

$P_{Benzene} = \frac{1}{2} \times 12.8 \text{ kPa} = 6.4 \text{ kPa}$

$P_{Toluene} = \frac{1}{2} \times 3.85 \text{ kPa} = 1.925 \text{ kPa}$

Thus, the vapour will contain a high percentage of benzene than toluene.

19. (d) On applying Raoult's law,

$P_T = P^{\circ}_A x_A + P^{\circ}_B x_B$

$$P_T = P^{\circ}_A \times \frac{\frac{25.5}{119.5}}{\frac{25.5}{119.5} + \frac{40}{85}} + P^{\circ}_B \times \frac{\frac{40}{85}}{\frac{25.5}{119.5} + \frac{40}{85}} = 90.3 \text{ mmHg}$$

20. (a) According to Raoult's Law $P_t = p_A x_A + p_B x_B$

$x_A + x_B = 1$

$x_A = (1 - x_B)$

$P_t = p_B(1 - x_A) + p_A x_A = p_B - p_B x_A + p_A x_A \Rightarrow p_B + x_A(p_A - p_B)$

21. (a) When water is added to the solution of KI, concentration of KI will decreases thus vapour pressure increases.

22. (d) $P_t = X_A P_A + X_B P_B$

$P_t = \frac{1}{5} \times 440 + \frac{4}{5} \times 120 = 184 \text{ mm Hg}$

Mole fraction in vapour phase of pentane $P_t = P X_{pentane}$

$\frac{184}{440} = 0.478$

23. (d) $P_{Total} = P_A X_A + P_B X_B$

$= 80 \times \frac{3}{5} + 60 \times \frac{2}{5} = 48 + 24 = 72 \text{ torr}$

24. (d) Ethanol-acetone mixture shows positive deviation due to weaker A-B interaction in comparison to A-A or B-B interaction.

Pure ethanol molecules are hydrogen bonded. When acetone is added, its molecules get in between the ethanol molecules and break some of the hydrogen bonds between them.

Thus, the intermolecular attractive interactions are weakens and causes increase in observed vapour pressure. Hence, the solution shows positive deviation from Raoult's law.

25. (c) The solutions which obey Raoult's law over the entire range of concentration are known as Ideal solutions. Two essential conditions for ideal solution,

$\Delta_{mix} H = 0$, i.e., no heat should be absorbed or evolved during mixing

$\Delta_{mix} V = 0$

26. (a) An azeotrope is a mixture of two or more liquids which contained some concentration of vapour and gaseous phases.

There are two types of azeotropic mixtures, minimum boiling azeotropes and maximum boiling azeotropes.

Maximum boiling azeotropes, these azeotropes have more boiling point than its constitute liquids, these liquid show negative deviation from raoult's law, hence, are also known as negative azeotropes.

Minimum boiling azeotropes, these azeotropes have lesser boiling point that its constitute liquids, these liquid show positive deviation from raoult's law, hence, are also known as positive azeotropes.

Solution showing negative deviation from Raoult's law form maximum boiling azeotrope.

Water and Nitric acid → forms maximum boiling azeotrope

27. (b) In case of an ideal solution $\Delta H_{mix} = 0$

$\Delta U_{mix} = 0$ but $\Delta S_{mix} \neq 0$

According to 3rd law of thermodynamics:

$\Delta G = \Delta H - T\Delta S$

$\Delta G_{mix} \neq 0$

28. (a) For an ideal solution: $\Delta S_{mix} > 0$

As entropy increases after mixing in ideal solutions.

29. (b) Acetone and ethanol shows positive deviation from Raoults law, it forms a minimum boiling azeotrope. Bonding between acetone and ethanol are weaker as compared to ethanol – ethanol and acetone – acetone.

34. **(a)** Higher the value of i, higher will be the value of T_b or vice-versa.

Electrolyte	i × M
NaCl	$2 \times 0.05 = 0.1$
KCl	$2 \times 0.1 = 0.2$
$MgSO_4$	$2 \times 0.1 = 0.2$
NaCl	$2 \times 1 = 2$

35. **(d)** As we know, osmotic pressure is directly proportional to the molar concentration of the solution and inversely proportional to molar mass of solute. Means with increase in molar concentration of solution, osmotic pressure increases.

Therefore,

$$\pi = CRT \Rightarrow \pi = \frac{n_2RT}{V} = \frac{W_2RT}{MV}$$

Molar mass of the given solutes decreases in the order:

Sucrose > Glucose > Urea

Hence, decreasing order of osmotic pressure of these solutions is:

$P_2 > P_1 > P_3$

36. **(d)** Assuming that given solution is dilute solution therefore, applying the formula for relative lowering of vapour pressure as,

$$\frac{\Delta P}{P_A^0} = \frac{n_B}{n_A} = \frac{w_B}{m_B}.\frac{m_A}{w_A}$$

$$\frac{20}{100} = \frac{8}{m_B}.\frac{114}{114}$$

$$m_B = \frac{8 \times 100}{20} = 40 g\,mol^{-1}$$

37. **(b)** Solutions that have same osmotic pressure at a given temperature are called isotonic solutions.

38. **(a)** If molality of a dilute solution is doubled, the value of molal depression constant (K_f) will be unchanged because the value of molal depression constant will depend only on number of solute and solvent particle, as it is colligative property.

39. **(b)** Two colligative properties will be used to solve the question.

Glycol lowers the freezing point of water.

Glycol prevents the automobile engine from bursting due to expansion when water freezes. Glycol provides a wide temperature range in which the mixture remains in the liquid phase.

41. **(b)** For osmotic pressure:

$$\pi = CRT = \frac{w}{M} \times \frac{1000}{V} \times R \times T$$

$$M = \frac{1.26}{2.57 \times 10^{-3}} \times \frac{1000}{200} \times 0.083 \times 300$$

$$= 61038 \text{ g mol}^{-1}$$

42. **(b)** Depression in Freezing point $\Delta T_f = \frac{W_1 \times K_f \times 1000}{M_1 \times W_2}$

where, W_1 = Weight of solute

W_2 = Weight of solvent

M_1 = Molar mass of solute

K_f = Freezing point depression constant

Now, $\Delta T_f = \frac{1.86 \times 68.5 \times 1000}{342 \times 1000} = 0.372°C$

Now, $\Delta T_f = T° - T_f$

So, $T_f = 0 - 0.372 = -0.372°C$.

(Freezing point of purewater = 0°C.)

43. **(a)** $\Delta T_f = K_f\ m$

$$\Delta T_f = 5.12 \times \frac{1}{250} \times \frac{1000}{51.2} = 0.4\ K$$

44. **(b)** As solution is isotonic means osmotic pressure will be same

So, $\frac{10}{60} \times \frac{1000}{10^{-3}} = \frac{5}{x} \times \frac{1000}{100}$

$$\frac{1}{6} = \frac{50}{x}$$

(x) Molecular mass of solute = 300 g mol^{-1}

45. **(d)** The flow of solvent from dilute solution to the concentrated solution across a semipermeable membrane is due to osmosis.

That is from a solution of low concentration to a solution of high concentration.

48. (b) as $\pi = \frac{n}{V}RT$ (Osmotic pressure formula)

$$M = \frac{m_2RT}{\pi V}$$

49. (c) Reverse osmosis - the direction of osmosis can be reversed if a larger pressure is applied on the solution side. Then, the pure solvent flow out of the solution through the semipermeable membrane.

50. (a) Polymers and proteins are covalent compounds, therefore by measuring osmotic pressure of their solution, the molecular weight can be determined.

51. (d) Given: $w_1 = 0.15$ g

$W_2 = 15$ g $\quad \Delta T_b = 0.216°C$

$K_b = 2.16 \quad M = ?$

$$\Delta T_b = \frac{1000 \times 2.16 \times 0.15}{M\,(15)}$$

$$M = \frac{1000 \times 2.16 \times 0.15}{0.216 \times 15}$$

$M = 100$

52. (c) According to Raoult's law:

$$\frac{p_o - p_s}{p_o} = \frac{w_1 \times M}{m \times w_2}$$

$$m = \frac{2.175 \times 78 \times 640}{40 \times 39.08} = 69.45$$

53. (c) Isotonic solution are the solution having same osmotic pressure.

Applying vant's Hoff equation

$\pi = CRT$

Osmotic pressure of 5% cane sugar solution

$$(\pi_1) = C \times R \times T = \frac{50\ g\,L^{-1}}{342} \times 0.0821 \times T$$

Osmotic pressure of 1% solution of substance

$$(\pi_2) = \frac{10\ g\,L^{-1}}{M} \times 0.0821 \times T_1$$

$$\therefore M(\text{molecular weight of x}) = \frac{342}{5} = 68.4$$

(mole fraction of solution)

So, mole fraction of solvent = 1 – 0.4 = 0.6

55. (c) Vapour pressure of pure solvent (P_A°) = 143 mm Hg, weight of solute (w) = 0.5 gram, weight of solvent (W) = 100 grams, molecular weight of solute (m) = 65 and molecular weight of solvent (M) = 154.

$$\frac{P_A^\circ - P}{P_A^\circ} = \frac{wM}{mW}$$

or $\frac{143 - P}{143} = \frac{0.5 \times 154}{65 \times 100} = 0.01$ or $P = 141.31$ mm Hg

56. (a) Weight of glucose = 10 g.

Weight of urea = 10 g and weight of sucrose = 10 g.

We know that the number of moles of glucose

$$(n_1) = \frac{\text{Weight}}{\text{Molecular weight}} = \frac{10}{180} = 0.05$$

Similarly number of moles of urea $(n_2) = \frac{10}{60} = 0.16$ and the

number of moles of sucrose $(n_3) = \frac{10}{342} = 0.03$

The osmotic pressure is a colligative property and it depends upon the number of moles of a solute. Since $n_2 > n_1 > n_3$, therefore $p_2 > p_1 > p_3$.

57. (a) Since relative lowering of vapour pressure is a colligative property, therefore it depends upon the number of solute particles or mole fraction of solute.

58. (a) There is no net movement of the solvent through the semipermeable membrane between two solutions of equal concentration.

59. (c) The properties which depend only upon the number of solute particles present in the solution irrespective of their nature are called as colligative properties. Lowering in vapour pressure, elevation in boiling point, depression in freezing point and osmotic pressure are colligative properties.

60. (b) Blood cells neither swell nor shrink in isotonic solution.

The solutions having same osmotic pressure are called isotonic solutions.

in aqueous solution:

$Ba(OH)_2 \rightleftharpoons Ba^{2+} + 2OH^-$

van't Hoff factor becomes 3 (1+2).

64. (c) Aluminium sulphate will 100% dissociate in aqueous solution so it will give total five ions.

$Al_2(SO_4)_3 \rightleftharpoons \underset{i=5}{2Al^{3+}} + 3SO_4^{2-}$

$K_4[Fe(CN)_6] \rightleftharpoons \underset{i=5}{4K^+} + [Fe(CN)_6]^-$

65. (d) X must be going dissociation in water thus increasing vant's Hoff factor (i) as after dissolution, the number of solute particles increases.

66. (b) Depression in freezing point depends on vant's Hoff factor which depends on dissociation entities.

Freezing point depression is given by formula:

$\Delta T_f = i \times K_b \times m$

Where, ΔT_f = Freezing point depression

T_f = Freezing point of the solution (°C)

i = ionization or van't Hoff factor

K_f = cryoscopic constant (°C/m)

m = molality (mol/kg)

So, among 4 options

$Al_2(SO_4)_3$ will have $2Al^{3+} + 3SO_4^{2-} = 5$ entities exhibiting maximum depression in freezing point.

67. (b) The relationship between the depression in the freezing point and the molality of the solution is as given below.

$\Delta T_f = iK_f m$ ...(1)

Let α b the degree of dissociation of the weak acid.

The dissociation equilibrium of the weak acid is as represented below.

HA	$\rightleftharpoons$	$H^+ + A^-$
1		0 0
(1 – α)		α α

The Van't Hoff factor i is the total number of ions/molecules given by the dissociation of 1 molecule of solute.

$$i = \frac{\Delta T_f W_1}{K_f (1000) n_B}$$

$$= \frac{3.82 \times 45}{1.886 \times \left(\frac{5}{142}\right) \times 1000} = 2.63$$

69. (d) If vant's Hoff factor undergoes dissociation, it becon greater than one and for association less than 1 as the numb of solute particles decreases.

70. (d) The dissociation of the given ionic compound is,

$[Co(NH_3)_5(NO_2)]Cl \rightleftharpoons [CO(NH_3)_5NO_2]^+ + Cl^-$

1 0 0

1 – α 0 α

Depression in freezing point (ΔT_f) is given by,

$\Delta T_f = i \times K_f \times m$

where,

i = Van't Hoff Factor

$i = 1 + \alpha(n - 1)$ for dissociation

K_f = Cryoscopic Constant

(For water value of $K_f = 1.86$)

m = molality of solution

Here $\Delta Tf = 0 - (-0.00732) = 0.00732$

$$i = \frac{\Delta T_f}{K_f \times m} = \frac{0.00732}{1.86 \times 0.0020} = 1.86 \approx 2$$

71. (b) $\Delta T_f = i K_f m$

For,

	HX	$\rightleftharpoons$	H^+	+	X^-
t = 0	1		0		0
t at equilibrium	(1 – 0.20)		0.20		0.20

Total number of moles = 1 – 0.20 + 0.20 + 0.20 = 1.2

$\therefore \Delta T_f = 1.2 \times 1.86 \times 0.5 = 1.1160 \approx 1.12$ K

72. (c) Since $Al_2(SO_4)_3$ give maximum number of ions dissociation, therefore it will have the lowest freezing poin

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CHAPTER 2

Electrochemistry

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Electrochemical and Galvanic Cells

1. The **correct** value of cell potential in volt for the reaction that occurs when the following two half cells are connected, is *(2023-Manipur)*

$Fe^{2+}_{(aq)} + 2e^- \rightarrow Fe(s)$, $E^\circ = -0.44$ V

$Cr_2O^{2-}_{7(aq)} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$, $E^\circ = +1.33$ V

a. +1.77 V b. +2.65 V
c. +0.01 V d. +0.89 V

2. Two half cell reactions are given below. *(2022 Re)*

$Co^{3+} + e^- \rightarrow Co^{2+}$ $E^\circ_{Co^{2+}/Co^{3+}} = -1.81$ V

$2Al^{3+} + 6e^- \rightarrow 2Al(s)$ $E^\circ_{Al/Al^{3+}} = +1.66$ V

The standard EMF of a cell with feasible redox reaction will be:

a. −3.47 V b. +7.09 V
c. +0.15 V d. +3.47 V

3. Given below are half cell reactions: **[MR*]** *(2022)*

$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

$E^\circ_{Mn^{2+}/MnO_4^-} = -1.510$ V

$\frac{1}{2}O_2 + 2H^+ + 2e^- \rightarrow H_2O$

$E_{O_2/H_2O} = +1.223$ V

Will the permanganate ion, MnO^-_4 liberate O_2 from water in the presence of an acid?

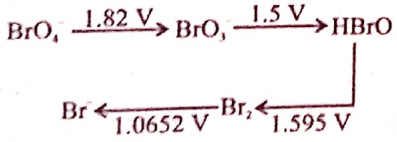
a. No because $E^\circ_{cell} = -2.733$ V

b. Yes, because $E^\circ_{cell} = +0.287$ V

c. No, because $E^\circ_{cell} = -0.287$ V

d. Yes, because $E^\circ_{cell} = +2.733$ V

4. Consider the change in oxidation state of Bromine corresponding to different emf values as shown in the diagram below : *(2018)*



Then the species undergoing disproportionation is

a. BrO_3^- b. BrO_4^-
c. HBrO d. Br_2

5. A button cell used in watches functions as following

$Zn(s) + Ag_2O(s) + H_2O(l) \rightleftharpoons 2Ag(s) + Zn^{2+}(aq) + 2OH^-(aq)$. If half cell potentials are

$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$; $E^\circ = -0.76$ V

$Ag_2O(s) + H_2O(l) + 2e^- \rightarrow 2Ag(s) + 2OH^-(aq)$, $E^\circ = 0.34$ V.

The cell potential will be: *(2013)*

a. 1.10 V b. 0.42 V
c. 0.84 V d. 1.34 V

6. Standard electrode potential for Sn^{4+}/Sn^{2+}couple is +0.15 V and that for the Cr^{3+}/Cr couple is −0.74 V. These two couples in their standard state are connected to make a cell. The cell potential will be: *(2011 Pre)*

a. +1.83 V b. +1.19 V
c. +0.89 V d. +0.18

7. A solution contains Fe^{2+}, Fe^{3+} and I^- ions. This solution was treated with iodine at 35°C. E° for Fe^{3+}/Fe^{2+} is + 0.77 V and E° for $I_2 / 2I^-$ = 0.536 V. The favourable redox reaction is: **[MR*]** *(2011 Mains)*

a. I^- will be oxidised to I_2
b. Fe^{2+} will be oxidised to Fe^{3+}
c. I_2 will be reduced to I^-
d. There will be no redox reaction

8. Consider the following relations for emf of a electrochemical cell: **[MR*]** *(2010 Mains)*

(A) emf of cell = (Oxidation potential of anode) −(Reduction potential of cathode)

(B) emf of cell = (Oxidation potential of anode) + (Reduction potential of cathode)

(C) emf of cell = (Reduction potential of anode) + (Reduction potential of cathode)

(D) emf of cell = (Oxidation potential of anode) −(Oxidation potential of cathode)

Which of the above relations are correct?

a. (C) and (A) b. (A) and (B)
c. (C) and (D) d. (B) and (D)

9. A hypothetical electrochemical cell is shown below
$A|A^+(xM)||B^+(yM)|B$
The emf measured is +0.20 V. The cell reaction is: *(2006)*
a. $A^+ + B \rightarrow A + B^+$
b. $A^+ + e^- \rightarrow A$; $B^+ + e^- \rightarrow B$
c. The cell reaction cannot be predicted
d. $A + B^+ \rightarrow A^+ + B$

10. If $E^\circ_{Fe^{2+}/Fe} = -0.441$ V and $E^\circ_{Fe^{3+}/Fe^{2+}} = 0.771$ V, the standard emf of the reaction: $Fe + 2Fe^{3+} \rightarrow 3Fe^{2+}$ will be: *(2006)*
a. 0.441 V b. 1.753 V
c. 1.212 V d. 0.211 V

11. Reduction potential for the following half-cell reactions are: *(1996)*
$Zn \rightarrow Zn^{2+} + 2e^-$; $E^\circ = +0.76$ V;
$Fe \rightarrow Fe^{2+} + 2e^-$; $E^\circ = +0.44$ V.
The EMF for the cell reaction
$Fe^{2+} + Zn \rightarrow Zn^{2+} + Fe$ will be
a. – 0.32 V b. + 1.20 V
c. – 1.20 V d. + 0.32 V

12. An electrochemical cell is set up as: pt, H_2 (1 atm)|HCl (0.1 M) || CH_3COOH (0.1 M) |H_2 (1 atm); Pt. The e.m.f. of this cell will not be zero, because: *(1995)*
a. Acids used in two compartments are different
b. e.m.f. depends on molarities of acids used
c. The temperature is constant
d. pH of 0.1 M HCl and 0.1 M CH_3COOH is not same

Nernst Equation

13. Given below are two statements : one is labelled as Assertion A and the other is labelled as Reason R: **[MR*]** *(2023)*
Assertion A: In equation $\Delta_rG = -nFE_{cell}$, value of Δ_rG depends on n.
Reasons R: E_{cell} is an intensive property and Δ_rG is an extensive property.
In the light of the above statements, choose the correct answer from the options given below:
a. A is false but R is true.
b. Both A and R are true and R is the correct explanation of A.
c. Both A and R are true but R is NOT the correct explanation of A.
d. A is true but R is false

14. The $E^\ominus$ values for *(2023-Manipur)*
$Al^+/Al = +0.55$ V and $Tl^+/Tl = -0.34$ V
$Al^{3+}/Al = -1.66$ V and $Tl^{3}/Tl = +1.26$V
Identify the incorrect statement
a. Al is more electropositive than Tl
b. Tl^{3+} is a good reducing agent than Tl^{1+}
c. Al^+ is unstable in solution
d. Tl can be easily oxidised to Tl^+ then Tl^{3+}

15. Standard electrode potential for the cell with cell reaction
$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$
is 1.1 V. Calculate the standard Gibbs energy change for the cell reaction. *(2022 Re)*
(Given F = 96487 C mol^{-1})
a. –200.27 J mol^{-1} b. –200.27 kJ mol^{-1}
c. –212.27 kJ mol^{-1} d. –212.27 J mol^{-1}

16. At 298 K, the standard electrode potentials of Cu^{2+}/Cu, Zn^{2+}/Zn, Fe^{2+}/Fe and Ag^+/Ag are 0.34 V, – 0.76 V, – 0.44 V and 0.80 V, respectively.
On the basis of standard electrode potential, predict which of the following reaction can not occur? **[MR*]** *(2022)*
a. $2CuSO_4(aq) + 2Ag(s) \rightarrow 2Cu(s) + Ag_2SO_4(aq)$
b. $CuSO_4(aq) + Zn(s) \rightarrow ZnSO_4(aq) + Cu(s)$
c. $CuSO_4(aq) + Fe(s) \rightarrow FeSO_4(aq) + Cu(s)$
d. $FeSO_4(aq) + Zn(s) \rightarrow ZnSO_4(aq) + Fe(s)$

17. Find the emf of the cell in which the following reaction takes place at 298 K
$Ni(s) + 2Ag^+(0.001\ M) \rightarrow Ni^{2+}(0.001\ M) + 2Ag(s)$
(Given that $E^\circ_{cell} = 10.5$ V, $\frac{2.303\,RT}{F} = 0.059$ at 298 K) *(2022)*
a. 1.05 V b. 1.0385 V
c. 1.385 V d. 0.9615 V

18. Identify the reaction from following having top position in EMF series (Std. red. potential) according to their electrode potential at 298 K. (2020-Covid)
a. $Fe^{2+} + 2e^- \rightarrow Fe(s)$ b. $Au^{3+} + 3e^- \rightarrow Au(s)$
c. $K^+ + 1e^- \rightarrow K(s)$ d. $Mg^{2+} + 2e^- \rightarrow Mg(s)$

19. For a cell involving one electron E°cell = 0.59 V at 298 K, the equilibrium constant for the cell reaction is:
$\left[\text{Given that } \frac{2.303RT}{F} = 0.059\text{V at T} = 298\text{K}\right]$ *(2019)*
a. 1.0×10^2 b. 1.0×10^5
c. 1.0×10^{10} d. 1.0×10^{30}

20. For the cell reaction
$2Fe^{3+}(aq) + 2I^-(aq) \rightarrow 2Fe^{2+}(aq) + I_2(aq)$
$E^\ominus_{cell} = 0.24$ V at 298 K. The standard Gibbs energy ($\Delta_rG^\ominus$) of the cell reaction is:
[Given that Faraday constant F = 96500 C mol^{-1}] *(2019)*
a. –46.32 kJ mol^{-1} b. –23.16 kJ mol^{-1}
c. 46.32 kJ mol^{-1} d. 23.16 kJ mol^{-1}

21. If the E°cell for a given reaction has a negative value, which of the following gives the correct relationships for the values of ΔG° and K_{eq}? **[MR*]** *(2016 - II)*
a. $\Delta G^0 < 0$; $K_{eq} > 1$ b. $\Delta G^0 < 0$; $K_{eq} < 1$
c. $\Delta G^0 > 0$; $K_{eq} < 1$ d. $\Delta G^0 > 0$; $K_{eq} > 1$

22. The pressure of H_2 required to make the potential of H_2 electrode zero in pure water at 298 K is: *(2016 - I)*

a. 10^{-4} atm b. 10^{-14} atm
c. 10^{-12} atm d. 10^{-10} atm

23. The pair of compounds that can exist together is: *(2014)*

a. $HgCl_2$, $SnCl_2$ b. $FeCl_2$, $SnCl_2$
c. $FeCl_3$, KI d. $FeCl_3$, $SnCl_2$

24. A hydrogen gas electrode is made by dipping platinum wire in a solution of HCl of pH = 10 and by passing hydrogen gas around the platinum wire at one atm pressure. The oxidation potential of electrode would be? *(2013)*

a. 0.059 V b. 0.59 V
c. 0.118 V d. 1.18 V

25. Standard reduction potentials of the half reactions are given below:

$F_2(g) + 2e^- \rightarrow 2F^-(aq)$; $E^\circ = +2.85$ V
$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$; $E^\circ = +1.36$ V
$Br_2(g) + 2e^- \rightarrow 2Br^-(aq)$; $E^\circ = +1.06$ V
$I_2(g) + 2e^- \rightarrow 2I^-(aq)$; $E^\circ = +0.53$ V

The strongest oxidising and reducing agents respectively are: **[MR*]** *(2012 Mains)*

a. Cl_2 and I_2 b. F_2 and I^-
c. Br_2 and Cl^- d. Cl_2 and Br^-

26. The Gibbs energy for the decomposition of Al_2O_3 at 500°C is as follows: $\frac{2}{3}Al_2O_3 \rightarrow \frac{4}{3}Al + O_2$ $\Delta G = +960$ kJ/mol^{-1}.

The potential difference needed for the electrolytic reduction of aluminium oxide (Al_2O_3) at 500°C at least: *(2012 Mains)*

a. 5.0 V b. 4.5 V
c. 2.5 V d. 3.0 V

27. The electrode potentials for $Cu^{2+}(aq) + e^- \rightarrow Cu^+(aq)$ and $Cu^+(aq) + e^- \rightarrow Cu(s)$ are + 0.15 V and + 0.50 V respectively. The value of $E^0_{Cu^{2+}/Cu}$ will be: *(2011 Pre)*

a. 0.150 V b. 0.500 V
c. 0.325 V d. 0.650 V

28. If the E°_{cell} for a given reaction has a negative value, then which of the following gives the correct relationships for the values of ΔG^0 and K_{eq}? *(2011 Pre)*

a. $\Delta G^0 > 0$; $K_{eq} < 1$ b. $\Delta G^0 > 0$; $K_{eq} > 1$
c. $\Delta G^0 < 0$; $K_{eq} > 1$ d. $\Delta G^0 < 0$; $K_{eq} < 1$

29. For the reduction of silver ions with copper metal, the standard cell potential was found to be +0.46 V at 25°C. The value of standard Gibbs energy, ΔG^0 will be: ($F = 96500$ C mol^{-1}) *(2010 Pre)*

a. –98.0 kJ b. –89.0 kJ
c. –89.0 J d. –44.5 kJ

30. Among the following which is the strongest oxidising agent? *(2009)*

a. Br_2 b. I_2
c. Cl_2 d. F_2

31. Given: i. $Cu^{2+} + 2e^- \rightarrow Cu$ $E^\circ_1 = 0.337$ V
ii. $Cu^{2+} + e^- \rightarrow Cu^+$ $E^\circ_2 = 0.153$ V

Electrode potential, E° for the reaction, $Cu^+ + e^- \rightarrow Cu$, will be: *(2009)*

a. 0.90 V b. 0.30 V
c. 0.38 V d. 0.52 V

32. On the basis of the following E° values, the strongest oxidising agent is: *(2008)*

$[Fe(CN)_6]^{4-} \rightarrow [Fe(CN)_6]^{3-} + e^-$; $E^0 = -0.35$ V
$Fe^{2+} \rightarrow Fe^{3+} + e^-$; $E^0 = -0.77$ V

a. $[Fe(CN)_6]^{3-}$ b. $[Fe(CN)_6]^{4-}$
c. Fe^{2+} d. Fe^{3+}

33. Standard free energies of formation (in kJ mol^{-1}) at 298 K are –237.2, –394.4 and –8.2 for H_2O (l), CO_2 (g) and pentane (g) respectively. The value of E° cell for the pentaneoxygen fuel cell is: *(2008)*

a. 0.0968 V b. 1.968 V
c. 2.0968 V d. 1.0968 V

34. The equilibrium constant of the reaction:

$Cu(s) + 2Ag^+(ag) \rightarrow Cu^{2+}(aq) + 2Ag(s)$;
$E^\circ = 0.46$ V at 298 K is: *(2007)*

a. 2.0×10^{10} b. 4.0×10^{10}
c. 4.0×10^{15} d. 2.4×10^{10}

35. The standard e.m.f. of a galvanic cell involving cell reaction with n = 2 is found to be 0.295 V at 25°C. The equilibrium constant of the reaction would be: *(2004)*

(Given F = 96500 C mol^{-1}; R = 8.314 J K^{-1} mol^{-1})

a. 4.0×10^{12} b. 1.0×10^{10}
c. 1.0×10^{10} d. 2.0×10^{11}

36. On the basis of the information available from the reaction:

$\frac{4}{3}Al + O_2 \rightarrow \frac{2}{3}Al_2O_3, \Delta G = -827$ kJ mol^{-1} of O_2,

the minimum e.m.f. required to carry out electrolysis of Al_2O_3 is (F = 96500 C mol^{-1}): **[MR*]** *(2003)*

a. 2.14 V b. 4.28 V
c. 6.42 V d. 8.56 V

37. The e.m.f. of a Daniell cell at 298 K is E_1.

$Zn|ZnSO_4$ (0.01M) $||$ $CuSO_4$ (1.0M)$|Cu$

When the concentration of $ZnSO_4$ is 1.0 M and that of $CuSO_4$ is 0.01 M, the e.m.f. is changed to E_2.
What is the relationship between E_1 and E_2: **[MR*]** *(2003)*

a. $E_1 > E_2$ b. $E_1 < E_2$
c. $E_1 = E_2$ d. $E_2 = 0 \neq E_1$

38. Zn gives H_2 gas with H_2SO_4 and HCl but not with HNO_3 because: *(2002)*

a. Zn act as oxidising agent when react with HNO_3
b. HNO_3 is weaker acid than H_2SO_4 and HCl
c. In electrochemical series Zn is above hydrogen
d. NO_3 is reduced in preference to hydronium ion

39. Standard electrode potential are

Fe^{+2}/Fe $\quad E^\circ = -0.44$

Fe^{+3}/Fe^{+2} $\quad E^\circ = 0.77$

If Fe^{+2}, Fe^{+3} and Fe block are kept together, then: *(2001)*

a. Fe^{+3} increases
b. Fe^{+3} decreases
c. $\frac{Fe^{+2}}{Fe^{+3}}$ remains unchanged
d. Fe^{+2} decreases

40. For the disproportionation of copper

$2Cu^+ \rightarrow Cu^{+2} + Cu$, E° is:- (Given E° for Cu^{+2}/Cu is 0.34 V and E° for Cu^{+2}/Cu^+ is 0.15 V) *(2000)*

a. 0.49 V
b. –0.19 V
c. 0.38 V
d. –0.38 V

41. Cell reaction is spontaneous when: *(2000)*

a. ΔG° is negative
b. ΔG° is positive
c. ΔE°_{Red} is positive
d. ΔE°_{red} is negative

42. Without losing its concentration, $ZnCl_2$ solution cannot be kept in contact with: *(1998)*

a. Au
b. Al
c. Pb
d. Ag

43. Which one of the following pairs of substances on reaction will not evolve H_2 gas? *(1998)*

a. Iron and H_2SO_4 (aqueous)
b. Iron and steam
c. Copper and HCl (aqueous)
d. Sodium and ethyl alcohol

44. For the cell reaction,

$Cu^{2+}(C_1aq) + Zn(s) \rightleftharpoons Zn^{2+}(C_2aq) + Cu(s)$ of an electrochemical cell. The change in free energy (ΔG) at a given

Conductance of Electrolytic Solutions

47. The conductivity of centimolar solution of KCl at 25°C is 0.0210 ohm^{-1} cm^{-1} and the resistance of the cell containing the solution at 25 °C is 60 ohm. The value of cell constant is: *(2023)*

a. 3.34 cm^{-1}
b. 1.34 cm^{-1}
c. 3.28 cm^{-1}
d. 1.26 cm^{-1}

48. Molar conductance of an electrolyte increase with dilution according to the equation: **[MR*]** *(2023-Manipur)*

$$\Lambda_m = \Lambda^\circ_m - A\sqrt{c}$$

Which of the following statements are **true**?

A. This equation applies to both strong and weak electrolytes.
B. Value of the constant A depends upon the nature of the solvent.
C. Value of constant A is same for both $BaCl_2$ and $MgSO_4$
D. Value of constant A is same for both $BaCl_2$ and $Mg(OH)_2$.

Choose the **most appropriate** answer from the options given below:

a. (A) and (B) only
b. (A), (B) and (C) only
c. (B) and (C) only
d. (B) and (D) only

49. The molar conductance of NaCl, HCl and CH_3COONa at infinite dilution are 126.45, 426.16 and 91.0 S cm^2 mol^{-1} respectively. The molar conductance of CH_3COOH at infinite dilution is. Choose the right option for your answer. **[MR*]** *(2021)*

a. 390.71 S cm^2 mol^{-1}
b. 698.28 S cm^2 mol^{-1}
c. 540.48 S cm^2 mol^{-1}
d. 201.28 S cm^2 mol^{-1}

50. The molar conductivity of 0.007 M acetic acid is 20 S cm^2 mol^{-1}. What is the dissociation constant of acetic acid? Choose the correct option. **[MR*]** *(2021)*

$$\begin{bmatrix} \Lambda^\circ_{H^+} = 350\ S\ cm^2 mol^{-1} \\ \Lambda^\circ_{CH_3COO^-} = 50\ S\ cm^2 mol^{-1} \end{bmatrix}$$

55. Which of the following expressions correctly represents the equivalent conductance at infinite dilution of $Al_2(SO_4)_3$. Given that $\Lambda^\circ_{Al^{3+}}$ and $\Lambda^\circ_{SO_4^{2-}}$ are the equivalent conductances at infinite dilution of the respective ions? *(2010 Mains)*

a. $2\Lambda^\circ_{Al^{3+}} + 3\Lambda^\circ_{SO_4^{2-}}$

b. $\Lambda^\circ_{Al^{3+}} + \Lambda^\circ_{SO_4^{2-}}$

c. $\left(\Lambda^\circ_{Al^{3+}} + \Lambda^\circ_{SO_4^{2-}}\right) \times 6$

d. $\frac{1}{3}\Lambda^\circ_{Al^{3+}} + \frac{1}{2}\Lambda^\circ_{SO_4^{2-}}$

56. An increase in equivalent conductance of a strong electrolyte with dilution is mainly due to: *(2010 Pre)*

a. Increase in number of ions

b. Increase in ionic mobility of ions

c. 100% ionisation of electrolyte at normal dilution

d. Increase in both i.e. number of ions and ionic mobility of ions

57. The equivalent conductance of $\frac{M}{32}$ solution of a weak mono basic acid is 8.0 mho cm^2 and at infinite dilution is 400 mho cm^2. The dissociation constant of this acid is: *(2009)*

a. 1.25×10^{-6}

b. 6.25×10^{-4}

c. 1.25×10^{-4}

d. 1.25×10^{-5}

58. Kohlrausch's law states that at: *(2008)*

a. Infinite dilution, each ion makes definite contribution to equivalent conductance of an electrolyte, whatever be the nature of the other ion of the electrolyte

b. Finite dilution, each ion makes definite contribution to equivalent conductance of an electrolyte, whatever be the nature of the other ion of the electrolyte

c. Infinite dilution, each ion makes definite contribution to equivalent conductance of an electrolyte depending on the nature of the other ion of the electrolyte

d. Infinite dilution, each ion makes definite contribution to conductance of an electrolyte whatever be the nature of the other ion of the electrolyte

59. At infinite dilution equivalent conductances of Ba^{+2} and Cl^- ions are 127 and 76 $ohm^{-1}\ cm^{-1}\ eq^{-1}$ respectively. Equivalent conductance of $BaCl_2$ at infinite dilution is: *(2000)*

a. 139.5

b. 101.5

c. 203

d. 279

becomes hot because of: *(1995)*

a. Energised electrons moving to the other end

b. Minor perturbation in the energy of atoms

c. Resistance of the metal

d. Mobility of atom in the metal

Electrolytic Cells and Electrolysis

63. On electrolysis of dil sulphuric acid using Platinum (Pt) electrode, the product obtained at anode will be: *(2020)*

a. Oxygen gas

b. H_2S gas

c. SO_2 gas

d. Hydrogen gas

64. The number of Faradays (F) required to produce 20 g of calcium from molten $CaCl_2$ (Atomic mass of Ca = 40 g mol^{-1}) is: *(2020)*

a. 2

b. 3

c. 4

d. 1

65. During the electrolysis of molten sodium chloride, the time required to produce 0.10 mol of chlorine gas using a current of 3 amperes is: *(2016 - II)*

a. 220 minutes

b. 330 minutes

c. 55 minutes

d. 110 minutes

66. The number of electrons delivered at the cathode during electrolysis by a current of 1 ampere in 60 seconds is: (charge on electron = 1.60×10^{-19} C) **[MR*]** *(2016 - II)*

a. 3.75×10^{20}

b. 7.48×10^{23}

c. 6×10^{23}

d. 6×10^{20}

67. When 0.1 mol MnO_4^{2-} is oxidised, the quantity of electricity required to completely oxidise MnO_4^{2-} to MnO_4^- is: *(2014)*

a. 96500 C

b. 2×96500 C

c. 9650 C

d. 96.50 C

68. The weight of silver (atomic weight = 108) displaced by a quantity of electricity which displaces 5600 mL of O_2 at STP will be: *(2014)*

a. 10.8 g

b. 54.0 g

c. 108.0 g

d. 5.4 g

69. Al_2O_3 is reduced by electrolysis at low potentials and high currents. If 4.0×10^4 amperes of current is passed through molten Al_2O_3 for 6 hours, what mass of aluminium is produced? (Assume 100% current efficiency. Atomic mass of Al = 27 g mol^{-1}) *(2009)*

a. 8.1×10^4 g
b. 2.4×10^5 g
c. 1.3×10^4 g
d. 9.0×10^3 g

70. 4.5 g of aluminium (atomic mass 27 amu) is deposited at cathode from Al^{3+} solution by a certain quantity of electric charge. The volume of hydrogen produced at STP from H^+ ions in solution by the same quantity of electric charge will be: *(2005)*

a. 22.4 L
b. 32.8 L
c. 5.6 L
d. 11.2 L

71. In electrolysis of NaCl when Pt electrode is taken then H_2 is liberated at cathode while with Hg cathode it forms sodium amalgam: [MR*] *(2002)*

a. Hg is more inert than Pt
b. More voltage is required to reduce H^+ at Hg than at Pt
c. Na is dissolved in Hg while it does not dissolve in Pt
d. Concentration of H^+ ions is larger when Pt electrode is taken

72. A 5 ampere current is passed through a solution of zinc sulphate for 40 minutes. The amount of zinc deposited at the cathode is: *(1996)*

a. 0.4065 g
b. 65.04 g
c. 40.65 g
d. 4.065 g

73. When $CuSO_4$ is electrolysed using platinum electrodes: [MR*] *(1993)*

a. Copper is liberated at cathode, sulphur at anode
b. Copper is liberated at cathode, oxygen at anode
c. Sulphur is liberated at cathode, oxygen at anode
d. Oxygen is liberated at cathode, copper at anode

Batteries, Fuel Cells and Corrosion

74. In a typical fuel cell, the reactants (R) and product (P) are [MR*] *(2020-Covid)*

a. $R = H_{2(g)}, O_{2(g)}; P = H_2O_{(\ell)}$
b. $R = H_{2(g)}, O_{2(g)}, Cl_{2(g)}; P = HClO_{4(aq)}$
c. $R = H_{2(g)}, N_{2(g)}; P = NH_{3(aq)}$
d. $R = H_{2(g)}, O_{2(g)}; P = H_2O_{2(\ell)}$

75. Zinc can be coated on iron to produce galvanized iron but the reverse is not possible. It is because: *(2016 - II)*

a. Zinc has lower negative electrode potential than iron
b. Zinc has higher negative electrode potential than iron
c. Zinc is lighter than iron
d. Zinc has lower melting point than iron

76. A device that converts energy of combustion of fuels like hydrogen and methane, directly into electrical energy is known as: *(2015)*

a. Electrolytic cell
b. Dynamo
c. Ni-Cd cell
d. Fuel cell

77. The efficiency of a fuel cell is given by: *(2007)*

a. $\Delta G/\Delta S$
b. $\Delta G/\Delta H$
c. $\Delta S/\Delta G$
d. $\Delta H/\Delta G$

Answer Key

1. (a)	2. (d)	3. (b)	4. (c)	5. (a)	6. (c)	7. (a)	8. (d)	9. (d)	10. (c)
11. (d)	12. (d)	13. (b)	14. (b)	15. (c)	16. (a)	17. (None)	18. (b)	19. (c)	20. (a)
21. (c)	22. (b)	23. (b)	24. (b)	25. (b)	26. (c)	27. (c)	28. (a)	29. (b)	30. (d)
31. (d)	32. (d)	33. (d)	34. (c)	35. (b)	36. (a)	37. (a)	38. (d)	39. (b)	40. (c)
41. (a)	42. (b)	43. (c)	44. (b)	45. (d)	46. (b)	47. (d)	48. (d)	49. (a)	50. (b)
51. (d)	52. (c)	53. (a)	54. (a)	55. (b)	56. (b)	57. (d)	58. (a)	59. (a)	60. (b)
61. (d)	62. (a)	63. (a)	64. (d)	65. (d)	66. (a)	67. (c)	68. (c)	69. (a)	70. (c)
71. (b)	72. (d)	73. (b)	74. (a)	75. (b)	76. (d)	77. (b)			

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Explanations

... according to the given E° values, $Cr_2O_7^{2-}$ will undergo reduction and Fe will undergo oxidation.

$E^\circ_{cell} = E^\circ_C - E^\circ_A$

$= (1.33) - (-0.44)$

$= +1.77$ V

2. (d) $E^\circ_{cell} = E^\circ_{cathode\ (R.P)} - E^\circ_{Anode\ (R.P)}$

$= 1.81 - (-1.66)$

$= 1.81 + 1.66$

$= 3.47$ V

3. (b) The first half cell reaction is given as,

$$MnO_4^- + 8H^+ + 5e^- \xrightarrow{(+7 \to +2)\ \text{Reduction occurs}} Mn^{2+} + 2H_2O$$

Here oxidation. state of Mn in reactant is +7 and in product is +2. It means reduction is occuring here. Therefore, this reaction will occur at cathode.

Second half cell reaction is given as-

$$\frac{1}{2}O_2 + 2H^+ + 2e^- \xrightarrow{(0 \to -2)\ \text{Oxidation occurs}} 2H_2O$$

Therefore, this reaction will occur at anode. From both the half cell reactions, the complete balanced reaction will be-

$$2MnO_4^- + 6H^+ \to 2Mn^{+2} + 3H_2O + \frac{5}{2}O_2$$

$E^\circ_{cell} = E_{cathode} - E_{anode}$

$= 1.510 - 1.223 = 0.287$ V

Positive E°_{cell} value suggests that the given hall cell reactions will occur.

4. (c) If any compound undergoes oxidation as well as reduction in the same reaction, disproportionstion reaction will occur. In other words, that compound will have an element with atleast three different oxidation numbers.

Here, first we will calculate ox. no. of Br in all compounds as,

$$\underset{(+7)}{BrO_4^-} \to \underset{(+5)}{BrO_3^-} \to \underset{(+1)}{HBrO} \to \underset{(0)}{Br_2} \to \underset{(-1)}{Br}$$

Here, max ox. st. of Br so Can't further oxidised.

in all these, oxidation as well as reduction is possible.

Lowest ox. st. of Br, so can's further reduced.

Note: To show disprapartionation reaction in electrochemisrty,

$\Delta G^0 < 0$ i.e. $E^0_{Cell} > 0$ $[\Delta G^0 = -nFE^0_{Cell}]$

ΔG^0 = Standard Gibb's energy change,

E^0_{Cell} = Cell potential (standard), n= no. of e^-_g involved,

F = Faraday's constant

The expression for cell potential is,

$E^0_{Cell} = E^0_{Cathode} - E^0_{anode}$

In above reaction, two reactions undergoes disproportionation which are given as,

$\overset{+1}{H}\overset{}{B}\overset{}{r}O \to \overset{0}{B}r_2, E^0_{HBrO/Br_2} = 1.595$ V'

$\overset{+1}{H}\overset{}{B}\overset{}{r}O \to \overset{+5}{B}rO_3^-, E^\circ_{BrO_3^-/HBrO} = 1.5$ V

E°_{cell} for the disproportionation of HBrO,

$E^\circ_{cell} = E^\circ_{HBrO/Br_2} - E^\circ_{BrO_3^-/HBrO}$

$= 1.595 - 1.5 = 0.095$ V = +ve

Hence, option (c) is correct answer.

5. (a) The expression for cell potential is given as,

$E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$

$= 0.76 - (-0.34) = 1.1$ V

6. (c) $E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$

$Sn^{4+} + 2e^- \to Sn^{2+}$ $E^\circ = 0.15$V

For reduction potential

$Cr^{3+} + 3e^- \to Cr$ $E^\circ = -0.74$V

$E^\circ_{cell} = 0.15 - (-0.74) = 0.89$ V

7. (a) For favourable redox reaction, cell potential value should be positive. The cell reactions are given as,

$2I^- \longrightarrow I_2 + 2e^-$ $E^0_{oxi} = -0.536$V

$Fe^{3+} + e^- \longrightarrow Fe^{2+}$ $E^0_{red} = 0.77$V

$2Fe^{3+} + 2I^- \longrightarrow 2Fe^{2+} + I_2$

$E^0 = E^0_{oxi} + E^0_{red}$

$= -0.536 + 0.77$

$= 0.234$ i.e. positive

Therefore, the favourable reaction is oxidation of iodide ion to iodine.

8. (d) When both reduction potential are given

$E^\circ_{cell} = E^\circ_{cathode\ (Red)} - E^\circ_{anode\ (Red)}$

When reduction & oxidation potential are given

$E^\circ_{cell} = E^\circ_{cathode\ (Red)} + E^\circ_{anode\ (Oxid)}$

When both oxidation potential are given

$E^\circ_{cell} = E^\circ_{anode\ (Oxid)} - E^\circ_{cathode\ (Oxid)}$

9. (d) From given expression:

At anode : $A \to A^+ + e^-$

At cathode : $B^+ + e^- \to B$

Therefore, the cell reaction is:

$A + B^+ \to A^+ + B$

10. (c) $E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$

$Fe^{2+} + 2e^- \to Fe$ $E^\circ = -0.441$V ...(i)

$Fe^{3+} + e^- \to Fe^{2+}$ $E^\circ = 0.771$V ...(ii)

For complete reaction, multiply second reaction with 2 then add with equation 1.

then we get,

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$Fe + 2Fe^{3} \rightarrow 3Fe^{2+}$

$E^{\circ} = 0.771 - (-0.441)$

$= 1.212$ V

11. (d) $E^{\circ}_{Zn/Zn^{+2}} = +0.76$ V

$E^{\circ}_{Fe/Fe^{2+}} = 0.44$V

For the reaction,

$Fe^{2+} + 2e^{-} \rightarrow Fe$

The value of E^{0}_{cell} will be,

$E^{\circ}_{Fe/Fe^{2+}} = -0.44$ V

To get desired reaction,

$Fe^{2+} + Zn \rightarrow Zn^{2+} + Fe$

We have to add both the E^{0} values

i.e.,

$E^{0}_{new} = E^{0}_{zn/zn^{2+}} + E^{0}_{Fe/Fe^{2+}}$

Hence,

E.M.F. $= +0.76 - 0.44 = +0.32$ V

12. (d) As it is a concentration cell and the concentration of ions in two electrolyte solutions (HCl and CH_3COOH) are different, therefore e.m.f. of this cell will not be zero.

13. (b) Free energy is extensive property, and E°_{Cell} is an intensive property $\Delta_r G$ is depends on the 'n' which is number of electron transferred in the reaction $\Delta_r G = -nFE^{\circ}$

14. (b) According to the given E° values, Tl^{3+} acts as an oxidising agent.

15. (c) $Zn(s) + Cu^{+2}(aq) \rightarrow Zn^{+2}(aq) + Cu(s)$

Given, $E^{\circ}_{cell} = 1.1$V

The value of $n = 2$ for this reaction

$\Delta G^{\circ} = -nFE^{\circ}_{cell}$

$= -2 \times 96487 \times 1.1 = -212, 271.4$J

$= -212.27$ kJ

16. (a) SRP $\Rightarrow$ Standard Reduction Potential values:

Therefore reactivity order is-

$E^{\circ}_{Zn^{2+}/Zn} < E^{\circ}_{Fe^{2+}/Fe} < E^{\circ}_{Cu^{2+}/Cu} < E^{\circ}_{Ag^{+}/Ag}$

Reactivity order : Zn > Fe > Cu > Ag

In case of displacement reaction, more reactive metals (lower SRP) can displace less reactive metals (higher SRP) from their salt solution.

$CuSO_{4(aq.)} + 2Ag_{(s)} \rightarrow Cu_{(s)} + Ag_2SO_{4(aq.)}$

Reaction is not possible

as Ag is less reactive metal compare to Cu.

17. (None)

$Ni(s) + 2Ag^{+}$ (0.001 M) $\rightarrow Ni^{+2}$ (0.001 M) $+ 2Ag(s)$

$E_{cell} = E^{\circ}_{cell} - \frac{0.059}{n}\log\frac{[Ni^{+2}]^{1}}{[Ag^{+}]^{2}}$

$E_{cell} = 10.5 - \frac{0.059}{2}\log\frac{10^{-3}}{(10^{-3})^{2}}$

$= 10.5 - \frac{0.059}{2}\log 10^{+3}$

$= 10.5 - \frac{0.059}{2} \times 3\log 10$

$= 10.5 - \frac{0.059}{2} \times 3 = 10.4115$ V

(Calculated answer is not given in options)

18. (b) $Au^{3+} + 3e^{-} \rightarrow Au(s)$ $E^{\circ} = 1.40$ V

$Fe^{2+} + 2e^{-} \rightarrow Fe(s)$ $E^{\circ} = -0.44$ V

$Mg^{2+} + 2e^{-} \rightarrow Mg(s)$ $E^{\circ} = -2.36$ V

$K^{+} + 1e^{-} \rightarrow K(s)$ $E^{\circ} = -2.93$ V

Au^{3+} occupies the top position in the electrochemical series

19. (c) The Nernst equation can be written as,

$E_{Cell} = E^{0}_{Cell} - \frac{2.303RT}{nF}\log Q$

Given, $n = 1$ & $\frac{2.303RT}{F} = 0.059$V

So, it can also be written as,

$E_{cell} = E^{\circ}_{cell} - \frac{0.059}{n}\log Q$ ... (i)

(here, Q is the ratio of concentration of product ions and reactant ions, At equilibrium, $Q = K_{eq}$ and $E_{cell} = 0$)

$0 = E^{\circ}_{cell} - \frac{0.059}{1}\log K_{eq}$ (from equation (i))

$\log K_{eq} = \frac{E^{\circ}_{cell}}{0.059} = \frac{0.59}{0.059} = 10$

$K_{eq} = 10^{10} = 1 \times 10^{10}$

20. (a) $\Delta G^{0} = -nFE^{0}_{cell}$ ...(i)

Where ΔG^{0} = Standard Gibb's Energy

n = no. of electrons involved

F = Faraday's constant

from equation (i), Standard Gibb's Energy is calculated as,

E^{0}_{Cell} = standard electrode potential

$= -2 \times 96500 \times 0.24$

$= -46320$J mol^{-1} $= \frac{-46320}{1000} = -46.32$ kJ/mol

21. (c) $\Delta G^{\circ} = -nFE^{\circ}$ cell

When E° cell = (–ve)

Then so, ΔG° = (+ve) $\Delta G > 0$

Also, $\Delta G^{\circ} = -2.303$ RT log K_{eq}

$\therefore K_{eq} < 1$

22. (b) $2H^{+} + 2e^{-} \rightarrow H_2$

$E = E^{\circ} - \frac{0.059}{2}\log\frac{P_{H_2}}{(H^{+})^{2}}$

$0 = 0 - \frac{0.059}{2}\log\frac{P_{H_2}}{(10^{-7})^{2}}$

As log 1 = 0, put in above equation

$$\log 1 = \log \frac{P_{H_2}}{(10^{-5})^2}$$

$$\frac{P_{H_2}}{(10^{-5})^2} = 1$$

$\log 1 = 0$

$P_{H_2} = (10^{-5})^2 = 10^{-10}$ atm.

23. **(b)** Sn^{2+} cannot reduce Fe^{2+}, because both wants , further oxidation to form Sn^{4+} and Fe^{3+}, none of them wants to reduce therefore, $FeCl_2$ and $SnCl_2$ can exists together.

24. **(b)** The electrode reaction is,

$$\frac{1}{2}H_2 \rightarrow H^+ + e^-$$

$H_2 \rightarrow 2H^+ + e^-$, $[H_2] = 1$

$P^H = 10$, $P^H = -\log_{10}[H^+]$

$[H^+] = 10^{-P^H}$

$[H^+] = 10^{-10}$

Applying Nernst Equation,

$$E_{Cell} = E^0_{Cell} - \frac{0.0591}{n}\log\frac{[H^+]^2}{[H_2]}$$

$$= 0.0 - \frac{0.0591}{2} \times \frac{2\log[H^+]}{1}$$

$= -0.0591 \times \log[10^{-10}]$

$= -0.0591 \times -10 \log 10^{10}$

$= 0.591$ V

25. **(b)** Among all options, F_2 is the best oxidising agent with highest reduction potential.

$F_2 + 2e^- \rightarrow 2F^-$ $\quad E^\circ = -2.85$ V

I^- is the weakest oxidising agent

$I_2 + 2e^- \rightarrow 2I^-$

26. **(c)** $\Delta G^\circ = -nFE^\circ$

$F = 96500$, $\Delta G^\circ = +960 \times 10^3$ J mol^{-1}

$$\frac{2}{3}Al_2O_3 \rightarrow \frac{4}{3}Al + O_2$$

Total number of Al atoms in $Al_2O_3 = \frac{2}{3} \times 2 = \frac{4}{3}$

$Al^{3+} + 3e^- \rightarrow Al$

As $3e^-$ change occur for each Al atom

$$\therefore \text{Total } n = \frac{4}{3} \times 3 = 4$$

$$E^\circ = -\frac{\Delta G^\circ}{nF} = -\frac{960 \times 1000}{4 \times 96500} \Rightarrow E^\circ = -2.48 \approx -2.5 \text{ V}$$

27. **(c)** $Cu^{2+} + e^- \rightarrow Cu^+$ $\quad G_1 = -n\ 0.15$ F

$Cu^+ + e^- \rightarrow Cu$ $\quad G_2 = -n \times 0.50$ F

$Cu^{2+} + 2e^- \rightarrow Cu$ $\quad G_3 = ?$

$\Delta G_3 = \Delta G_1 + \Delta G_2$

$-2FE^\circ = -1F \times 0.15 \times (-1F \times 0.5)$

$$E^\circ = \frac{0.65}{2} = 0.325 \text{ V}$$

28. **(a)** $\Delta G^\circ = -nFE^\circ$ if $E^\circ = -ve$

ΔG° is positive $\quad \Delta G = -RT \log K_{eq}$ & $K_{eq} = -ve$

So, $\Delta G^\circ > 0$ but $K_{eq} < 1$.

29. **(b)** $Cu + 2Ag^{2+} \rightarrow Cu^{2+} + 2Ag$

$\Delta G^\circ = -n E^\circ F$

$n = 2$

$= -2 \times 96500 \times 0.46$

$= -89$ kJ

30. **(d)** F_2 is the strongest oxidising agent with highest positive oxidation potential.

31. **(d)**

$Cu^{2+} + 2e^- \rightarrow Cu$; $\quad E^0_1 = 0.337$ V

$Cu^{2+} + e^- \rightarrow Cu^+$ $\quad E^0_2 = 0.153$ V

Required reaction

For $Cu^+ + e^- \rightarrow Cu$; $\quad E_3^\circ = ?$

Applying, $\Delta G^\circ = -nFE^\circ$, $\Delta G_3^\circ = \Delta G_1^\circ - \Delta G_2^\circ$

$-(n_3FE_3^\circ) = -(n_1FE_1^\circ) - (-n_2FE_2^\circ)$

or $E_3^\circ = 2 \times E_1^\circ - E_2^\circ$

or $E_3^\circ = (2 \times 0.337) - 0.153 = 0.52$ V.

32. **(d)** $[Fe(CN)_6]^{3-} \rightarrow [Fe(CN)_6]^{4-}$, $E^\circ = +0.35$ V

$Fe^{3+} \rightarrow Fe^{2+}$; $E^\circ = +0.77$ V

Higher the +ve reduction potential, stronger will be the oxidising agent. Oxidising agent oxidises other compounds and gets itself reduced easily.

33. **(d)** $C_5H_{12}(g) + 8O_2(g) \rightarrow 5CO_2(g) + 6H_2O\ (l)$

$\Delta G^\circ = [(-394.4 \times 5) + (-237.2 \times 6)] - [(-8.2) + (8 \times 0)]$

$= -3387.5$ kJ

Note that the standard free energy change of elementary substances is taken as zero.

For the fuel cell, the complete cell reaction is the combination of the following two half reactions:

$C_5H_{12}(g) + 10H_2O\ (l) \rightarrow 5CO_2(g) + 32H^+ + 32e^-$ and

$8O_2(g) + 32H^+ + 32e^- \rightarrow 16H_2O\ (l)$

Therefore, the number of electrons exchanged is 32 here. means n = 32. This is the trickiest part of the problem.

$\Delta G^\circ = -nFE^\circ$

$= -3387.5 \times 10^3$ J

$= -32 \times 96500$ J V$^{-1} \times E^\circ$

Thus $E^\circ = 1.0968$ V

34. **(c)** As, $E^\circ_{cell} = \frac{0.0591}{n}\log K_c$

$$\therefore 0.46 = \frac{0.0591}{2}\log K_c$$

$$\therefore \log K_c = \frac{2 \times 0.46}{0.0591} = 15.57$$

Or K_c = antilog $15.57 = 3.7 \times 10^{15} \approx 4 \times 10^{15}$

35. **(b)** $E = E^\circ - \frac{0.0591}{n}\log_{10} Q$ at 25°C

At equlibirium, $E = 0$, $Q = K$

$$0 = E^\circ - \frac{0.0591}{n}\log_{10}K$$

$$K = \text{antilog}\left[\frac{nE^\circ}{0.0591}\right]$$

$$K = \text{antilog}\left[\frac{2\times0.295}{0.0591}\right]$$

$$= \text{antilog } 10 = 1 \times 10^{10}$$

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36. (a) The minimum e.m.f. required to carry out electrolysis of Al_2O_3 is calculated by the formula,

For O_2 $\Delta G = -nFE^0$ ...(i)

For 1 mol of Al n = 3 (i.e. $3e^-$) are required

$\therefore$ for $\frac{4}{3}$ moles of Al $= 3\times\frac{4}{3} = 4n$ will be required

Put this value in equation (i)

$$E^\circ = \frac{\Delta G}{-nF} = \frac{-827000}{-4\times96500} = 2.14 \text{ V}$$

37. (a) Cell reaction can be represented as

$Zn + Cu^{2+} \rightarrow Cu + Zn^{2+}$

Using the relation, $E_{cell} = E^0_{Cell} - \frac{0.0591}{n}\log\frac{[\text{anode}]}{[\text{cathode}]}$

$$= E^0_{Cell} - \frac{0.0591}{n}\log\frac{[Zn^{2+}]}{[Cu^{2+}]}$$

Substituting the given values in two cases.

$$E_1 = E^0 - \frac{0.0591}{2}\log\frac{0.01}{1.0}$$

$$= E^0 - \frac{0.0591}{2}\log10^{-2}$$

$$= E^0 + \frac{0.0591}{2}\times2 \text{ or } (E^0 + 0.0591)\text{V}$$

$$E_2 = E^0 - \frac{0.0591}{2}\log\frac{1}{0.01}$$

$$= E^0 - \frac{0.0591}{2}\log10^{2}$$

$$= E^0 - \frac{2\times0.0591}{2} \text{ or } (E^0 - 0.0591)\text{V}$$

Thus, $E_1 > E_2$

38. (d) Zn is on top position in electrochemical series. So Zn displaces H_2 from dilute H_2SO_4 and HCl with liberation of H_2.

$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$

On the other hand, HNO_3 is an oxidizing agent, so it oxidises the hydrogen obtained into H_2O and NO_3^- itself gets reduced.

39. (b) Conversion of Fe^{2+} to Fe is non-spontaneous while converting Fe^{3+} to Fe^{2+} is spontaneous. So, Fe^{3+} will be spontaneously converted to Fe^{2+}. So, Fe^{3+} will decreases.

40. (c) For the reaction $2Cu^+ \rightarrow Cu^{2+} + Cu$

The cathode is Cu^+/Cu and anode is Cu^+/Cu^{2+}

Given, $Cu^{2+} + 2e^- \rightarrow Cu$; $E^\circ_1 = 0.34$ V ...(i)

$Cu^{2+} + e^- \rightarrow Cu^+$; $E^\circ_2 = 0.15$ V ...(ii)

$Cu^+ + e^- \rightarrow Cu$; $E^\circ_3 = ?$ ...(iii)

Now $\Delta G^\circ_1 = -nFE^\circ_1 = -2\times0.34\times F$

$\Delta G^\circ_2 = -1\times0.15\times F, \Delta G^\circ_3 = -1\times E^\circ_3\times F$

Again $\Delta G^\circ_1 = \Delta G^\circ_2$

$\Rightarrow -0.68\ F = -0.15\ F - E^\circ_3\times F$

$\Rightarrow E^\circ_3 = 0.68 - 0.15 = 0.53$ V

As, $E^\circ_{cell} = E^\circ_{cathode}(Cu^+/Cu) - E^\circ_{anode}(Cu^{2+}/Cu^+)$

$= 0.53 - 0.15 = 0.38$ V

41. (a) For a cell reaction to be spontaneous ΔG° should be negative. As $\Delta G^\circ = -nFE^\circ$, So the value will be negative only when E° is positive. n = number of electrons involved, F = Value of Faraday.

42. (b) In electrochemical series, Al is placed above Zn and all other are present below Zn. So, aluminium displaces zinc from $ZnCl_2$ solution. Hence, it cannot be kept in contact with Al.

The reaction is given as,

$2Al + 3ZnCl_2 \rightarrow 2AlCl_3 + 3Zn$

43. (c) $Fe + \text{dil. } H_2SO_4 \rightarrow FeSO_4 + H_2\uparrow$

$3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2\uparrow$

Steam

Cu is present below H in electrochemical series

$Cu + \text{dil. } HCl \rightarrow$ no reaction

$2Na + C_2H_5OH \rightarrow 2C_2H_5ONa + H_2\uparrow$

44. (b) For concentration cell

$$E = \frac{RT}{nF}\ln\frac{C_2}{C_1}$$

In it R, T, and F are constant

So, E is based upon $\ln C_2/C_1$

$\Delta G = -nFE$

$$= -nF\times\frac{RT}{nF}\ln\frac{C_2}{C_1}$$

So, at constant temperature ΔG depend upon $\ln C_2/C_1$.

45. (d) Nernst equation is $E = E^\circ - \frac{0.059}{2}\log K$

$$\Rightarrow E^\circ = \frac{0.059}{2}\log K \quad (E = 0 \text{ at equilibrium condition})$$

$$\Rightarrow 1.1 = \frac{0.059}{2}\log K \Rightarrow K = 10^{-37}$$

46. (b) A cation with maximum value of standard reduction potential, has the strongest oxidising power.

47. (d) Conductivity = Conductance × Cell constant

Conductivity = (1/resistance)

Cell constant = Conductivity × Resistance

Cell constant = $0.0210 \times 60 = 1.26\ Cm^{-1}$

48. (d) Among the given statements, both B and D are correct.

49. (a) Given the molar conductance of ionic compounds,

$\Lambda_m^{\circ}(NaCl) = 126.45\ S\ cm^2\ mol^{-1}$

$\Lambda_m^{\circ}(HCl) = 426.16\ S\ cm^2\ mol^{-1}$

$\Lambda_m^{\circ}(CH_3COONa) = 91.0\ S\ cm^2\ mol^{-1}$

According to Kohlrausch law of independent migration of ions :

$\Lambda_m^{\circ}(CH_3COOH) = \Lambda_m^{\circ}(CH_3COONa) + \Lambda_m^{\circ}(HCl) - \Lambda_m^{\circ}(NaCl)$

$91.0\ S\ cm^2\ mol^{-1} + 426.16\ S\ cm^2\ mol^{-1} - 126.45\ S\ cm^2\ mol^{-1}$

$= 390.71\ S\ cm^2\ mol^{-1}$

Hence, the molar conductance of CH_3COOH at infinite dilution = $390.71\ S\ cm^2\ mol^{-1}$

50. (b) $\Lambda_m = 20\ S\ cm^2\ mol^{-1}$

$\Lambda^{\circ}_{m\,CH_3COOH} = \Lambda^{\circ}_{CH_3COO^-} + \Lambda^{\circ}_{mH^+}$

$= 50 + 350 = 400\ S\ cm^2\ mol^{-1}$

at any concentration C, degree of dissociation is defined as,

$$\alpha = \frac{\Lambda_m}{\Lambda_m^0}$$

where Λ_m = molar conductivity at concentration C

where Λ_m^0 = limiting molar conductitivity or molar conductivity at infinite dilution

Therefore,

$$\alpha = \frac{\Lambda_m}{\Lambda_m^{\circ}} = \frac{20}{400} = \frac{1}{20}$$

Dissociation constant K_a, for weak electrolyte like acetic acid is calculated as,

$$K_a = \frac{C\alpha^2}{1-\alpha} \simeq C\alpha^2 = 7\times10^{-3}\times\left(\frac{1}{20}\right)^2$$

$$= 7\times10^{-3}\times\frac{1}{4}\times10^{-2}$$

$$K_a = 1.75\times10^{-5}\ mol\ L^{-1}$$

Dissociation constant = 1.75×10^{-5} mol L^{-1}

51. (d) Concentration = 0.5 mol dm^{-3}, K = 5.76×10^{-3} S cm^{-1}

T = 298 K

Molar conductivity of $AgNO_3$ is calculated as,

$$\Lambda_m = \frac{\kappa}{C}$$

Where, κ = electrolyte conductivity

C = Concentration

$$= \frac{5.76\times10^{-3}\,S\,cm^{-1}}{0.5\times10^{-3}\,mol\,cm^{-3}} = 11.52\,S\,mol^{-1}\,cm^2$$

52. (c) According to Kohlrausch's law of limiting molar conductivity:

$$\alpha = \frac{\Lambda_m}{\Lambda_m^{\circ}} = \frac{9.54}{238} = 0.04008$$

% Dissociation (α) = 4.008%

53. (a) According to Kohlrausch's law of limitation molar conductivities

$\Lambda^{\circ}_{m(NH_4OH)} = \Lambda^{\circ}_{m(NH_4Cl)} + \Lambda^{\circ}_{m(NaOH)} - \Lambda^{\circ}_{m(NaCl)}$

$= \Lambda^{\circ}_{m(NH_4^+)} + \Lambda^{\circ}_{m(Cl^-)} + \Lambda^{\circ}_{m(Na^+)} + \Lambda^{\circ}_{m(OH^-)}$

$- \Lambda^{\circ}_{m(Na^+)} - \Lambda^{\circ}_{m(Cl^-)}$

$= \Lambda^{\circ}_{m(NH_4^+)} + \Lambda^{\circ}_{m(OH^-)}$

54. (a) According to Kohlrausch's law of molar conductivity:

$\Lambda_m^{\circ}(CH_3COOH)$

$= \Lambda_m^{\circ}(CH_3COONa) + \Lambda_m^{\circ}(HCl) - \Lambda_m^{\circ}(NaCl)$

$= 91.0 + 425.9 - 126.4 = 390.5\ S\ cm^2\ mol^{-1}$

55. (b) At infinite dilution, when dissociation is complete, each ion makes a definite contribution towards molar conductance of the electrolyte irrespective of the nature of the other ion with which it is associated.

Hence $\Lambda^{\circ}_{Al_2(SO_4)_3} = \Lambda^{\circ}_{Al^{3+}} + \Lambda^{\circ}_{SO_4^{2-}}$

56. (b) In strong electrolytes, equivalence conductance increases by increasing mobility of ions in the solution. This increase by increasing the dilution, number of atoms of electrolyte should remain constant.

57. (d) $\Lambda_c = 8$ mho cm^2, $\Lambda^{\circ}_m = 400$ mho cm^2

$$\alpha = \frac{\Lambda_m}{\Lambda^{\circ}_m}$$

$$\alpha = \frac{8}{400} = 0.02$$

$$K_c = \frac{c\alpha^2}{1-\alpha} \Rightarrow \frac{\frac{1}{32}\times0.02\times0.02}{1-0.2\ (\sim1)}$$

$$= 1.25\times10^{-5}$$

58. (a) According to the Kohlrausch's law: "at infinite dilution each ion contributes in fixed value towards equivalent conductance irrespective of the other ion in combination with a fixed temperature"

59. (a) $\Lambda_{\infty}(BaCl_2) = \frac{1}{2}\times\Lambda^{\infty}_{Ba^{2+}} + \frac{1}{1} + \Lambda^{\infty}_{Cl^-}$

$$= \frac{1}{2}\times127 + 76 = 63.5 + 76 = 139.5$$

60. (b) specific Conductance or Conductivity (κ) is defined as

$$\kappa = \frac{\ell}{R\times a} \text{ or } \frac{1}{R}\cdot\frac{\ell}{a}$$

Where R = Resistance and $\frac{\ell}{a}$ is cell constant

So, $0.012\ \Omega^{-1}cm^{-1} = \frac{\ell}{55\ \Omega\times a}$

$$\frac{\ell}{a} = 0.012\times55\ \Omega \Rightarrow 0.66\ cm^{-1}$$

61. (d) Molar conductance of CH_3COOH

$= \Lambda^{\infty}_{(CH_3COONa)} + \Lambda^{\infty}_{m(HCl)} - \Lambda^{\infty}_{m(NaCl)}$

$= 91 + 426.16 - 126.45 = 390.71\ \Omega^{-1}\,cm^2\,mol^{-1}$

62. (a) Conductivity of heat in metals is due to the presence of free electrons or energised electrons, which move to the other end due to increase in temperature.

63. (a) The following reactions take place on electrolysis of dilute sulphuric acid on using Pt electrodes are:

At cathode: $4H^+ + 4e^- (aq) \rightarrow 2H_2(g)$

At anode: $2H_2O(l) \rightarrow O_2(g) + 4H^+ (aq) + 4e^-$

Thus,the product obtained at anode is O_2

64. (d) The balanced chemical reaction for electrolysis of molten $CaCl_2$ is given as,

$CaCl_2 \rightarrow Ca^{2+} + 2Cl^-$

According to this,

For every mole of Ca^{2+} ions reduced 2 moles of electrons are required. The charge carried by 1 mole of electrons is 1 F.

The molar mass of $CaCl_2$ is 111 $gmol^{-1}$ means 1 mole of $CaCl_2$ contains 1 mole of Ca^{2+} ions. therefore,

Electricity required to produce 40g Ca (as M.M of Ca = 40 g/m) = 2F

Therefore, electricity requited to produce 20 g Ca $= \frac{2F \times 20}{40} = 1F$

Hence, number to Faraday's (F) required to produce 20g Ca = 1F

65. (d) Given moles of Cl_2 gas = 0.1 mole, time = ?

Current I = 3 ampere

$NaCl \rightleftharpoons Na^+ + Cl^-$

$2Cl^- \rightarrow 1Cl_2 + 2e^-$

$\Downarrow$

2F

$Q = It \quad \Rightarrow t = \frac{Q}{I}$, Where Q = quantity of electricity

For 1 mole of Cl_2 produce, Faraday's required = 2F

quantity of electricity (or F) for 0.1 mol $Cl_2 = 0.1 \times 2 \times F$

$t = \frac{0.1 \times 2 \times 96500}{3} = 6433.33 \text{sec} = 107 \text{min} = 110 \text{min}$

66. (a) According to Faraday's law

$Q = ne$ ...(i)

where, n = no of electrons liberated at cathode

e=charge on electron

$Q = it$ ...(ii)

i = current

t = time

from equation (i) and (ii),

$ne = it$

$n = \frac{1 \times 60}{1.6 \times 10^{-19}} = 3.75 \times 10^{20}$ electrons

67. (c) $\overset{+6}{M}nO_4^{-2} \rightarrow \overset{+7}{M}nO_4^- + e^-$

0.1 mole 0.1 mole

$Q = nF = 0.1 \times 96500 = 9650$ C

68. (c) At STP, 1 mole of O_2 occupied 22.4 L

i.e. 22.4×10^3 ml

$\therefore$ no. of moles of O_2 corresponding to 5600 ml,

$NO_2 = \frac{5600}{22400} = \frac{1}{4}$

no. of moles of $O_2 = \frac{Wo_2}{Mo_2}$

By Faraday's second law,

[4 moles of e^- are produced by 1 mole of O_2 and 1 mole of e^-, are produced by 1 mole of Ag]

$\frac{W_{Ag}}{M_{Ag}} \times 1 = \frac{Wo_2}{Mo_2} \times 4$

$\frac{W_{Ag}}{108} \times 1 = \frac{1}{4} \times 4$ [As $M_{Ag} = 108$g & $\frac{Wo_2}{Mo_2} = \frac{1}{4}$]

$W_{Ag} = 108$g

69. (a) $Al^{3+} + 3e^- \rightarrow Al$

According to Faraday's 1st law

$w = \frac{E.i.z.t}{96500}$

$w = \frac{27 \times 4 \times 10^4 \times 6 \times 60 \times 60}{3 \times 96500} = 8.1 \times 10^4$ g

70. (c) According to Faraday's 2nd law

$\frac{w_{Al}}{\text{Equivalent weight Al}} = \frac{w_{H_2}}{\text{Equivalent weight } H_2}$

$\frac{4.5}{9} = \frac{\text{Volume of } H_2 \text{ at STP}}{11200}$

Volume corresponding to Equal weight of H_2 is

$= \frac{4.5 \times 11200}{9} = 5.6$L

71. (b) When NaCl is dissolved in water, it ionise as

$NaCl \rightleftharpoons Na^+ + Cl^-$

Water also dissociate as:

$H_2O \rightleftharpoons H^+ + OH^-$

H^+ ions gain electron and change into neutral atom due to low discharge potential.

At cathode:

$H^+ + e^- \rightarrow H$

$H + H \rightarrow H_2$

At anode:

$Cl^- \rightarrow Cl + e^-$

$Cl + Cl \rightarrow Cl_2$

If mercury is used as cathode, H^+ ions will not discharge at mercury because mercury has a high hydrogen over voltage. Na^+ ions will get discharged at cathode in preference of H^+ ions giving sodium, which dissolves in mercury to form sodium amalgam.

72. (d) Current (I) = 5 ampere and time (t) = 40 minutes = 2400 seconds.

Amount of electricity passed (Q) = I × t = 5 × 2400 = 12000 C

Now $Zn^{2+} + 2e^- \rightarrow Zn$ (1 mole = 65.39)

Since two charges (*i.e.* 2 × 96500 C) deposits 65.39 g of zinc, therefore 12000 C will deposit

$$= \frac{65.39 \times 12000}{2 \times 96500} = 4.065 \text{ g of zinc}$$

73. (b) $CuSO_4 \rightleftharpoons Cu^{2+} + SO_4^{2-}$

$H_2O \rightleftharpoons H^+ + OH^-$

At cathode : $Cu^{2+} + 2e^- \rightarrow Cu$

At anode : $4OH^- \rightarrow 2H_2O + O_2 + 4e^-$

74. (a) Cell reaction involved in hydrogen-oxygen fuel cell is

$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

Thus R = $H_2(g)$, $O_2(g)$; P = $H_2O(l)$

75. (b) Zn have a higher (–ve) electrode potential that is more reactive than Fe. It is coated on iron substances to provide resistance against rusting such a process is called galvanisation. But in reverse, that is Fe cannot be coated on Zn, as corrosion will occur. In above, Zn displaces Fe from its salt solution.

76. (d) The combustion reactions are redox reactions. Hence they are used to produce electricity.

Fuel cells are the galvanic cells in which the energy of combustion of fuels is directly converted into electrical energy.

In the fuel cells, the reactants are continuously supplied to the electrodes from the reservoir.

The fuel used is hydrogen gas, methane or methanol.

77. (b) The fuel cell thermodynamic efficiency is given by the ratio of the Gibbs function change to the enthalpy change in the overall cell reaction. The Gibbs function change measures the electrical work and the enthalpy change is a measure of the heating value of the fuel.

$$\text{Thermal Efficiency } (\eta) = \frac{\text{Useful energy}}{\Delta H}$$

$$\text{Hence; } \eta_{ideal} = \frac{\Delta G}{\Delta H}$$

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CHAPTER 3

Chemical Kinetics

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Rate of Chemical Reactions

1. For a reaction $3A \rightarrow 2B$
The average rate of appearance of B is given by $\frac{\Delta[B]}{\Delta t}$. The **correct** relation between the average rate of appearance of B with the average rate of disappearance of A is given in option: *(2023-Manipur)*

a. $\frac{-\Delta[A]}{\Delta t}$ b. $\frac{-3\Delta[A]}{2\Delta t}$

c. $\frac{-2\Delta[A]}{3\Delta t}$ d. $\frac{\Delta[A]}{\Delta t}$

2. The correct options for the rate law that corresponds to overall first order reaction is *(2023-Manipur)*

a. Rate = $k[A]^0[B]^2$ b. Rate = $k[A][B]$

c. Rate = $k[A]^{1/2}[B]^2$ d. Rate = $k[A]^{-1/2}[B]^{3/2}$

3. For a chemical reaction [**MR***] *(2022 Re)*
$4A + 3B \rightarrow 6C + 9D$
rate of formation of C is 6×10^{-2} mol L^{-1} s^{-1} and rate of disappearance of A is 4×10^{-2} mol L^{-1} s^{-1}. The rate of reaction and amount of B consumed in interval of 10 seconds, respectively will be:

a. 10×10^{-2} mol L^{-1} s^{-1} and 30×10^{-2} mol L^{-1}
b. 1×10^{-2} mol L^{-1} s^{-1} and 30×10^{-2} mol L^{-1}
c. 10×10^{-2} mol L^{-1} s^{-1} and 10×10^{-2} mol L^{-1}
d. 1×10^{-2} mol L^{-1} s^{-1} and 10×10^{-2} mol L^{-1}

4. For the chemical reaction
$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$
The correct option is: *(2019)*

a. $-\frac{1}{3}\frac{d[H_2]}{dt} = -\frac{1}{2}\frac{d[NH_3]}{dt}$ b. $-\frac{d[N_2]}{dt} = 2\frac{d[NH_3]}{dt}$

c. $-\frac{d[N_2]}{dt} = \frac{1}{2}\frac{d[NH_3]}{dt}$ d. $3\frac{d[H_2]}{dt} = 2\frac{d[NH_3]}{dt}$

5. The rate of the reaction
$2N_2O_5 \rightarrow 4NO_2 + O_2$ can be written in three ways:
$\frac{-d[N_2O_5]}{dt} = k[N_2O_5]$
$\frac{d[NO_2]}{dt} = k'[N_2O_5]$
$\frac{d[O_2]}{dt} = k''[N_2O_5]$
The relationship between k and k′ and between k and k″ are: *(2011 Mains)*

a. $k' = 2k$; $k'' = 2k$ b. $k' = k$; $k'' = k$

c. $k' = 2k$; $k'' = k$ d. $k' = 2k$; $k'' = k/2$

6. For the reaction $N_2O_5(g) \rightarrow 2NO_2(g) + \frac{1}{2}O_2(g)$ the value of rate of disappearance of N_2O_5 is given as 6.25×10^{-3} mol $L^{-1}s^{-1}$. The rate of formation of NO_2 and O_2 is given respectively as: *(2010 Pre)*

a. 1.25×10^{-2} mol $L^{-1}s^{-1}$ and 6.25×10^{-3} mol $L^{-1}s^{-1}$
b. 6.25×10^{-3} mol $L^{-1}s^{-1}$ and 6.25×10^{-3} mol $L^{-1}s^{-1}$
c. 1.25×10^{-2} mol $L^{-1}s^{-1}$ and 3.125×10^{-3} mol $L^{-1}s^{-1}$
d. 6.25×10^{-3} mol $L^{-1}s^{-1}$ and 3.125×10^{-3} mol $L^{-1}s^{-1}$

7. In the reaction
$BrO_3^-(aq) + 5Br^-(aq) + 6H^+ \rightarrow 3Br_2(l) + 3H_2O(l)$.
The rate of appearance of bromine is related to rate of disappearance of bromide ions as following: [**MR***] *(2009)*

a. $\frac{d[Br_2]}{dt} = -\frac{5}{3}\frac{d[Br^-]}{dt}$ b. $\frac{d[Br_2]}{dt} = \frac{5}{3}\frac{d[Br^-]}{dt}$

c. $\frac{d[Br_2]}{dt} = \frac{3}{5}\frac{d[Br^-]}{dt}$ d. $\frac{d[Br_2]}{dt} = -\frac{3}{5}\frac{d[Br^-]}{dt}$

8. For the reaction
$N_2 + 3H_2 \rightarrow 2NH_3$, if $\frac{d[NH_3]}{dt} = 2 \times 10^{-4}$ mol L^{-1} s^{-1}
the value of $\frac{-d[H_2]}{dt}$ would be: *(2009)*

a. 4×10^{-4} mol L^{-1} s^{-1} b. 6×10^{-4} mol L^{-1} s^{-1}

c. 1×10^{-4} mol L^{-1} s^{-1} d. 3×10^{-4} mol L^{-1} s^{-1}

9. Consider the reaction $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ The equality relationship between $(d[NH_3]/dt)$ and $-(d[H_2]/dt)$ is: *(2006)*

a. $(d[NH_3]/dt) = -(1/3)(d[H_2]/dt)$
b. $+(d[NH_3]/dt) = -(2/3)(d[H_2]/dt)$
c. $+(d[NH_3]/dt) = -(3/2)(d[H_2]/dt)$
d. $(d[NH_3]/dt) = -(d[H_2]/dt)$

10. For the reaction $2A + B \rightarrow 3C + D$ which of the following does not express the reaction rate? *(2006)*

a. $-d[C]/3dt$ b. $-d[B]/dt$

c. $d[D]/dt$ d. $-d[A]/2dt$

11. $3A \rightarrow 2B$, rate of reaction $\frac{+d[B]}{dt}$ is equal to: **[MR*]** *(2002)*

a. $-\frac{3}{2}\frac{d[A]}{dt}$ b. $-\frac{2}{3}\frac{d[A]}{dt}$

c. $-\frac{1}{3}\frac{d[A]}{dt}$ d. $+2\frac{d[A]}{dt}$

12. For the reaction $H^+ + BrO_3^- + 3Br^- \rightarrow 5Br_2 + H_2O$ which of the following relation correctly represents the consumption and formation of products: *(2000)*

a. $\frac{d[Br^-]}{dt} = -\frac{3}{5}\frac{d[Br_2]}{dt}$ b. $\frac{d[Br^-]}{dt} = \frac{3}{5}\frac{d[Br_2]}{dt}$

c. $\frac{d[Br^-]}{dt} = -\frac{5}{3}\frac{d[Br_2]}{dt}$ d. $\frac{d[Br^-]}{dt} = \frac{5}{3}\frac{d[Br_2]}{dt}$

13. For the reaction $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ the rate of reaction is expressed as: *(1997)*

a. $\frac{\Delta[H_2]}{\Delta t} = \frac{1}{2}\frac{\Delta[I_2]}{\Delta t} = -\frac{\Delta[HI]}{\Delta t}$

b. $-\frac{\Delta[I_2]}{\Delta t} = -\frac{\Delta[H_2]}{\Delta t} = \frac{1}{2}\frac{\Delta[HI]}{\Delta t}$

c. $\frac{\Delta[I_2]}{\Delta t} = -\frac{\Delta[H_2]}{\Delta t} = \frac{\Delta[HI]}{2\Delta t}$

d. None of these

Factors Influencing Rate of a Reaction & Order of Reaction

14. For a certain reaction, the rate = $k[A]^2[B]$. When the initial concentration of A is tripled keeping concentration of B constant, the initial rate would *(2023)*

a. increase by a factor of three.

b. decrease by a factor of nine.

c. increase by a factor of six.

d. increase by a factor of nine

15. Mechanism of a hypothetical reaction **[MR*]** *(2017-Delhi)*

$X_2 + Y_2 \rightarrow 2XY$ is given below:

(i) $X_2 \rightarrow X + X$ (fast)

(ii) $X + Y_2 \rightleftharpoons XY + Y$ (slow)

(iii) $X + Y \rightarrow XY$ (fast)

The overall order of the reaction will be

a. 1.5 b. 1

c. 2 d. 0

16. The decomposition of phosphine (PH_3) on tungsten at low pressure is a first-order reaction. It is because the: *(2016-II)*

a. Rate is proportional to the surface coverage

b. Rate is inversely proportional to the surface coverage

c. Rate is independent of the surface coverage

d. Rate of decomposition is very low

17. In a reaction, A + B → Product, rate is doubled when the concentration of B is doubled, and rate increases by a factor of 8 when the concentrations of both the reactants (A and B) are doubled, rate law for the reaction can be written as: *(2012 Pre)*

a. Rate = $k[A]^2[B]$ b. Rate = $k[A][B]^2$

c. Rate = $k[A]^2[B]^2$ d. Rate = $k[A][B]$

18. The unit of rate constant for a zero order reaction is: *(2011 Main)*

a. $L^2\ mol^{-2}\ s^{-1}$ b. s^{-1}

c. $mol\ L^{-1}\ s^{-1}$ d. $L\ mol^{-1}\ s^{-1}$

19. Which one of the following statements for the order of a reaction is incorrect? *(2011 Pre)*

a. Order of reaction is always whole number

b. Order can be determined only experimentally

c. Order is not influenced by stoichiometric coefficient of the reactants

d. Order of reaction is sum of power to the concentration terms of reactants to express the rate of reaction

20. During the kinetic study of the reaction, $2A + B \rightarrow C + D$, following results were obtained

Run	[A] / mol L^{-1}	[B] / mol L^{-1}	Initial rate of formation of D/mol L^{-1} min^{-1}
I	0.1	0.1	6.0×10^{-3}
II	0.3	0.2	7.2×10^{-2}
III	0.3	0.4	2.88×10^{-1}
IV	0.4	0.1	2.40×10^{-2}

Based on the above data which one of the following is correct? **[MR*]** *(2010 Pre)*

a. rate = $k[A][B]^2$ b. rate = $k[A]^2[B]$

c. rate = $k[A][B]$ d. rate = $k[A]^2[B]^2$

21. For the reaction A + B → products, it is observed that: *(2009)*

A. On doubling the initial concentration of A only, the rate of reaction is also doubled and

B. On doubling the initial concentrations of both A and B, there is a change by a factor of 8 in the rate of the reaction.

The rate of this reaction is given by?

a. rate = $k[A][B]^2$ b. rate = $k[A]^2[B]^2$

c. rate = $k[A][B]$ d. rate = $k[A]^2[B]$

22. The bromination of acetone that occurs in acid solution is represented by this equation

$CH_3COCH_3(aq) + Br_2(aq) \rightarrow CH_3COCH_2Br(aq) + H^+(aq) + Br(aq)$

These kinetic data were obtained for given reaction concentrations

Initial concentration, M

$[CH_3COCH_3]$	$[Br_2]$	$[H^+]$
0.30	0.05	0.05
0.30	0.10	0.05
0.30	0.10	0.10
0.40	0.05	0.20

Initial rate, disappearance of Br_2, M s^{-1}
5.7×10^{-5}
5.7×10^{-5}
1.2×10^{-4}
3.1×10^{-4}

Based on these data, the rate equation is: [MR^] (2008)

a. Rate = $k[CH_3COCH_3][Br_2][H^+]$
b. Rate = $k[CH_3COCH_3][H^+]$
c. Rate = $k[CH = COCH_3][Br_2]$
d. Rate = $k[CH_3COCH_3][Br_2][H^+]^2$

23. The reaction of hydrogen and iodine monochloride is given as:

$H_2(g) + 2ICl(g) \rightarrow 2HCl(g) + I_2(g)$ The reaction is of first order with respect to H_2 (g) and ICl (g), following mechanisms were proposed.

Mechanism A:

$H_2(g) + 2ICl(g) \rightarrow 2HCl(g) + I_2(g)$

Mechanism B:

$H_2(g) + ICl(g) \rightarrow HI(g)$; slow

$HI(g) + ICl(g) \rightarrow 2HCl(g) + I_2(g)$; fast

Which of the above mechanism(s) can be consistent with the given information about the reaction? (2007)

a. A and B both
b. Neither A nor B
c. A only
d. B only

24. The rate of reaction between two reactants A and B decreases by a factor of 4, if the concentration of reactant B is doubled. The order of this reaction with respect to reactant B is: (2005)

a. –1
b. –2
c. 1
d. 2

25. If the rate of the reaction is equal to the rate constant, the order of the reaction is: (2003)

a. 0
b. 1
c. 2
d. 3

26. $2A \rightarrow B + C$, It would be a zero order reaction when: (2002)

a. The rate of reaction is proportional to square of concentration of A
b. The rate of reaction remains same at any concentration of A
c. The rate remains unchanged at any concentration of B and C
d. The rate of reaction doubles if concentration of B is increased to double

27. For the reaction $2N_2O_5 \rightarrow 4NO_2 + O_2$ rate and rate constant are 1.02×10^{-4} and 3.4×10^{-5} sec^{-1} respectively. Then concentration, of N_2O_5 at that time will be: (2001)

a. 1.732
b. 3
c. 1.02×10^{-4}
d. 3.4×10^5

28. The experimental data for the reaction,

$2A + B_2 \rightarrow 2AB$ is

Experiment	[A]	$[B_2]$	Rate (mole s^{-1})
1	0.50	0.50	1.6×10^{-4}
2	0.50	1.00	3.2×10^{-4}
3	1.00	1.00	3.2×10^{-4}

The rate equation for the above data is: (1997)

a. Rate = $k[A]^2[B]^2$
b. Rate = $k[A]^2[B]$
c. Rate = $k[B_2]$
d. Rate = $k[B_2]^2$

29. The given reaction

$2FeCl_3 + SnCl_2 \rightarrow 2FeCl_2 + SnCl_4$

is an example of: (1996)

a. Third order reaction
b. First order reaction
c. Second order reaction
d. None of these

30. The data for the reaction $A + B \rightarrow C$, is (1994)

Exp.	$[A]_0$	$[B]_0$	Initial rate
1	0.012	0.035	0.10
2	0.024	0.070	0.80
3	0.024	0.035	0.10
4	0.012	0.070	0.80

a. Rate = $k[A][B]^3$
b. Rate = $k[A]^2[B]^2$
c. Rate = $k[B]^3$
d. Rate = $k[B]^4$

Integrated Rate Equation & Half Life of Reactions

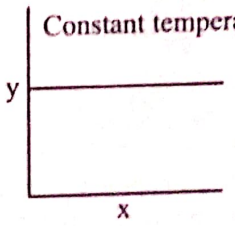
31. The half life of a first order reaction is 2000 years. If the concentration after 8000 years is 0.02 M, then the initial concentration was: (2022 Re)

a. 0.04 M
b. 0.16 M
c. 0.32 M
d. 0.08 M

32. For a first order reaction A→Products, initial concentration of A is 0.1 M, which becomes 0.001 M after 5 minutes. Rate constant for the reaction in min^{-1} is [MR^] (2022)

a. 0.2303
b. 1.3818
c. 0.9212
d. 0.4606

33. The given graph is a representation of kinetics of a reaction.



The y and x axes for zero and first order reactions, respectively are [MR*] (2022)

a. zero order (y = rate and x = concentration), first order (y = rate and x = $t_{1/2}$)
b. zero order (y = concentration and x = time), first order (y = $t_{1/2}$ and x = c concentration)
c. zero order (y = concentration and x = time), first order (y = rate constant and x = concentration)
d. zero order (y = rate and x = concentration), first order (y = $t_{1/2}$ and x = concentration)

34. The rate constant for a first order reaction is $4.606 \times 10^{-3}\ s^{-1}$. The time required to reduce 2.0 g of the reactant to 0.2 g is: *(2020)*

a. 200 s
b. 500 s
c. 1000 s
d. 100 s

35. The half-life for a zero order reaction having 0.02 M initial concentration of reactant is 100 s. The rate constant (in mol $L^{-1}\ s^{-1}$) for the reaction is *(2020-Covid)*

a. 2.0×10^{-4}
b. 2.0×10^{-3}
c. 1.0×10^{-2}
d. 1.0×10^{-4}

36. If the rate constant for a first order reaction is k, the time (t) required for the completion of 99% of the reaction is given by: [MR*] *(2019)*

a. $t = 0.693/k$
b. $t = 6.909/k$
c. $t = 4.606/k$
d. $t = 2.303/k$

37. When initial concentration of the reactant is doubled, the half-life period of a zero order reaction *(2018)*

a. Is halved
b. Is doubled
c. Is tripled
d. Remains unchanged

38. The correct difference between first and second order reactions is that: [MR*] *(2018)*

a. The rate of a first-order reaction does not depend on reactant concentrations; the rate of a second-order reaction does depend on reactant concentrations
b. The half-life of a first-order reaction does not depend on $[A]_0$; the half-life of a second-order reaction does depend on $[A]_0$
c. The rate of a first-order reaction does depend on reactant concentrations; the rate of a second-order reaction does not depend on reactant concentrations
d. A first-order reaction can catalyzed; a second-order reaction cannot be catalyzed

39. A first order reaction has a specific reaction rate of $10^{-2}\ s^{-1}$. How much time will it take for 20 g of the reactant to reduce to 5 g? *(2017-Delhi)*

a. 693.0 second
b. 238.6 second
c. 138.6 second
d. 346.5 second

40. The rate of a first-order reaction is 0.04 mol $L^{-1}\ s^{-1}$ at 10 seconds and 0.03 mol $L^{-1}\ s^{-1}$ at 20 seconds after initiation of the reaction. The half-life period of the reaction is: [MR*] *(2016 - I)*

a. 54.1 s
b. 24.1 s
c. 34.1 s
d. 44.1 s

41. The rate constant of the reaction A → B is 0.6×10^{-3} mole per second. If the concentration of A is 5 M, then concentration of B after 20 minutes is: *(2015 Re)*

a. 0.72 M
b. 1.08 M
c. 3.60 M
d. 0.36 M

42. When initial concentration of a reactant is doubled in a reaction, its half-life period is not affected. The order of the reaction is: *(2015)*

a. First
b. Second
c. More than zero but less than first
d. Zero

43. The half life of a substance in a certain enzyme catalysed reaction is 138 s. The time required for the concentration of the substance to fall from 1.28 mg L^{-1} to 0.04 mg L^{-1} is: *(2011 Mains)*

a. 690 s
b. 276 s
c. 414 s
d. 552 s

44. Half life period of a first-order reaction is 1386 seconds. The specific rate constant of the reaction is: *(2009)*

a. $0.5 \times 10^{-2}\ s^{-1}$
b. $0.5 \times 10^{-3}\ s^{-1}$
c. $5.0 \times 10^{-2}\ s^{-1}$
d. $5.0 \times 10^{-3}\ s^{-1}$

45. If 60% of a first order reaction was completed in 60 minutes, 50% of the same reaction would be completed in approximately: *(2007)*

a. 45 minutes
b. 60 minutes
c. 40 minutes
d. 50 minutes

(log 4 = 0.60, log 5 = 0.69)

46. In a first-order reaction A → B, if k is rate constant and initial concentration of the reactant A is 0.5 M, then the half-life is: *(2007)*

a. $\frac{\log 2}{k}$
b. $\frac{\log 2}{k\sqrt{0.5}}$
c. $\frac{\ln 2}{k}$
d. $\frac{0.693}{0.5k}$

47. For a first order reaction A → B, the reaction rate at reactant concentration of 0.01 M is found to be 2.0×10^{-5} mol $L^{-1}\ s^{-1}$. The half life period of the reaction is: *(2005)*

a. 227 s
b. 327 s
c. 527 s
d. 347 s

48. The reaction A → B follows first order kinetics. The time taken for 0.8 mole of A to produce 0.6 mole of B is 1 hour. What is the time taken for conversion of 0.9 mole of A to produce 0.675 mole of B: *(2003)*

a. 1 hour
b. 0.5 hour
c. 0.25 hour
d. 2 hour

49. The radioisotope, tritium $\left({}_{1}^{3}H\right)$ has a half-life of 12.3 years. If the initial amount of tritium is 32 mg, how many milligrams of it would remain after 49.2 years: [MR*] *(2003)*

a. 1 mg
b. 2 mg
c. 4 mg
d. 8 mg

50. A human body required the 0.01 Curie activity of radioactive substance after 24 hours. Half life of radioactive is 6 hours. Then maximum activity of radioactive substance that can be injected will be: *(2001)*

a. 0.08
b. 0.04
c. 0.16
d. 0.32

51. For a first-order reaction, the half-life period is independent of: *(1999)*

a. Initial concentration
b. Cube root of initial concentration
c. First power of final concentration
d. Square root of final concentration

52. The half-life of C_6^{14}, ($\lambda = 2.31 \times 10^{-4}$ per year) is: *(1999)*

a. 2×10^2 year
b. 3×10^3 year
c. 3.3×10^4 year
d. 4×10^3 year

Temperature Dependence of the Rate of a Reaction & Effect of Catalysts

53. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R: *(2023)*

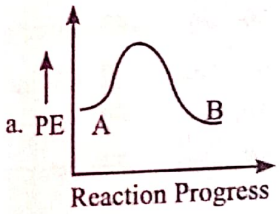
Assertion A: A reaction can have zero activation energy.

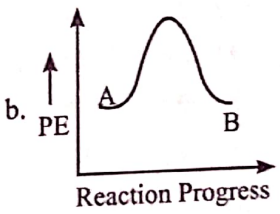
Reason R: The minimum extra amount of energy absorbed by reactant molecules so that their energy becomes equal to threshold value, is called activation energy.

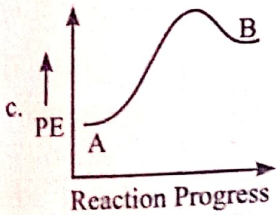
In the light of the above statements, choose the correct answer from the options given below:

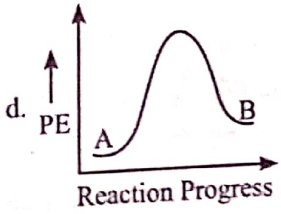
a. A is false but R is true.
b. Both A and R are true and R is the correct explanation of A.
c. Both A and R are true and R is NOT the correct explanation of A.
d. A is true but R is false.

54. For a reaction A → B, enthalpy of reaction is –4.2 kJ mol^{-1} and enthalpy of activation is 9.6 kJ mol^{-1}. The correct potential energy profile for the reaction is shown in option. *(2021)*

a. 

b. 

c. 

d. 

55. The slope of Arrhenius Plot (ln K v/s 1/T) of first order reaction is -5×10^3 K. The value of E_a of the reaction is. Choose the correct option for your answer. *(2021)*

[Given R = 8.314 JK^{-1} mol^{-1}]

a. 83.0 kJ mol^{-1}
b. 166 kJ mol^{-1}
c. –83 kJ mol^{-1}
d. 41.5 kJ mol^{-1}

56. The addition of a catalyst during a chemical reaction alters which of the following quantities? *(2016 - I)*

a. Activation energy
b. Entropy
c. Internal energy
d. Enthalpy

57. The activation energy of a reaction can be determined from the slope of which of the following graphs? *(2015)*

a. $\frac{\ln k}{T}$ vs. T
b. ln k vs. $\frac{1}{T}$
c. $\frac{T}{\ln k}$ vs. $\frac{1}{T}$
d. ln k vs. T

58. A reaction having equal energies of activation for forward and reverse reactions has: *(2013)*

a. $\Delta S = 0$
b. $\Delta G = 0$
c. $\Delta H = 0$
d. $\Delta H = \Delta G = \Delta S = 0$

59. What is the activation energy for a reaction if its rate doubles when the temperature is raised from 20°C to 35°C? (R = 8.314 J mol^{-1} K^{-1}) [MR*] *(2013)*

a. 342 kJ mol^{-1}
b. 269 kJ mol^{-1}
c. 34.7 kJ mol^{-1}
d. 15.1 kJ mol^{-1}

60. Activation energy (E_a) and rate constants (k_1 and k_2) of a chemical reaction of two different temperatures (T_1 and T_2) are related by: *(2012 Mains)*

a. $\ln\frac{k_1}{k_2} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$
b. $\ln\frac{k_2}{k_1} = \frac{-E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$
c. $\ln\frac{k_2}{k_1} = \frac{-E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$
d. $\ln\frac{k_2}{k_1} = \frac{-E_a}{R}\left(\frac{1}{T_2} + \frac{1}{T_1}\right)$

61. In a zero-order reaction for every 10°C rise of temperature, the rate is doubled. If the temperature is increased from 10°C to 100°C, the rate of the reaction will become: *(2012 Pre)*

a. 128 times
b. 256 times
c. 512 times
d. 64 times

62. The rate of the reaction $2NO + Cl_2 \rightarrow 2NOCl$ is given by the rate equation, rate = $k[NO]^2[Cl_2]$. The value of the rate constant can be increased by: *(2010 Mains)*

a. Increasing the temperature
b. Increasing the concentration of NO
c. Increasing the concentration of the Cl_2
d. Doing all of these

63. For an endothermic reaction, energy of activation is E_a and enthalpy of reaction is ΔH (both of these in kJ/mol). Minimum value of E_a will be: *(2010 Pre)*

a. Equal to zero
b. Less than ΔH
c. Equal to ΔH
d. More than ΔH

64. The rate constants k_1 and k_2 for two different reactions are $10^{16}.e^{-2000/T}$ and $10^{15}.e^{-1000/T}$ respectively. The temperature at which $k_1 = k_2$ is: [MR*] *(2008)*

a. $\frac{1000}{2.303}$K
b. 1000 K
c. $\frac{2000}{2.303}$K
d. 2000 K

65. The activation energy for a simple chemical reaction A → B is E_a in forward direction. The activation energy for reverse reaction: *(2003)*

a. Is negative of E_a
b. Is always less than E_a
c. Can be less than or more than E_a
d. Is always double of E_a

66. The temperature dependence of rate constant (k), of a chemical reaction is written in terms of Arrhenius. equation, $k = Ae^{-E_a/RT}$. Activation energy (E_a) of the reaction can be calculated by plotting: [MR*] *(2003)*

a. k vs T
b. k vs $\frac{1}{\log T}$
c. $\log k$ vs $\frac{1}{T}$
d. $\log k$ vs $\frac{1}{\log T}$

67. When a biochemical reaction is carried out in laboratory outside the human body in the absence of enzyme, then the rate of reaction obtained is 10^{-6} times, then activation energy of reaction in the presence of enzyme is: *(2001)*

a. $\frac{6}{RT}$
b. P is required
c. Different from, E_a obtained in laboratory
d. Can't say any things

68. Activation energy of a chemical reaction can be determined by: *(1998)*

a. Evaluating rate constant at standard temperature
b. Evaluating velocities of reaction at two different temperatures
c. Evaluating rate constants at two different temperatures
d. Changing concentration of reactants

69. By the action of enzymes, the rate of biochemical reaction: *(1994)*

a. Does not change
b. Increases
c. Decrease
d. Either (a) or (c)

Collision Theory of Chemical Reactions

70. In collision theory of chemical reaction, Z_{AB} represents [MR*] *(2020-Covid)*

a. The collision frequency of reactants, A and B
b. Steric factor
c. The fraction of molecules with energies equal to E_a
d. The fraction of molecules with energies greater than E_a

71. An increase in the concentration of the reactants of a reaction leads to change in: *(2020)*

a. Heat of reaction
b. Threshold energy
c. Collision frequency
d. Activation energy

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Answer Key

1. (c)	2. (d)	3. (b)	4. (c)	5. (d)	6. (c)	7. (d)	8. (d)	9. (b)	10. (a)
11. (b)	12. (a)	13. (b)	14. (d)	15. (a)	16. (a)	17. (a)	18. (c)	19. (a)	20. (a)
21. (a)	22. (b)	23. (d)	24. (b)	25. (a)	26. (b)	27. (b)	28. (c)	29. (a)	30. (c)
31. (c)	32. (c)	33. (d)	34. (b)	35. (d)	36. (c)	37. (b)	38. (b)	39. (c)	40. (b)
41. (a)	42. (a)	43. (a)	44. (b)	45. (a)	46. (c)	47. (d)	48. (a)	49. (b)	50. (c)
51. (a)	52. (b)	53. (c)	54. (a)	55. (d)	56. (a)	57. (b)	58. (c)	59. (c)	60. (c)
61. (c)	62. (a)	63. (d)	64. (a)	65. (c)	66. (c)	67. (c)	68. (c)	69. (b)	70. (a)
71. (c)									

Explanations

1. (c) The given reaction is:

$3A \rightarrow 2B$

Now,

$$r = -\frac{1}{3}\frac{\Delta[A]}{\Delta t} = +\frac{1}{2}\frac{\Delta[B]}{\Delta t}$$

$$+\frac{\Delta[B]}{\Delta t} = -\frac{2}{3}\frac{\Delta[A]}{\Delta t}$$

2. (d) Rate $= k[A]^{-1/2}[B]^{3/2}$

$$\text{Order} = -\frac{1}{2} + \frac{3}{2} = \frac{2}{2} = 1$$

3. (b) The given reaction is:

$4A + 3B \rightarrow 6C + 9D$

$$r = -\frac{1}{4}\frac{d[A]}{dt} = +\frac{1}{6}\frac{d[C]}{dt}$$

$$r = \frac{1}{6} \times 6 \times 10^{-2} = 1 \times 10^{-2}\ \text{mol L}^{-1}\ \text{s}^{-1}$$

$\therefore \quad r = 10^{-2}\ \text{mol L}^{-1}\ \text{s}^{-1}$ ...(i)

$$r = -\frac{1}{3}\frac{d[B]}{dt}$$ ...(ii)

On putting value of eq. (i) in eq. (ii), we get:

$\frac{-d[B]}{dt} = 3 \times 10^{-2}$ mol L^{-1} s^{-1}

B consumed in 10 seconds $= 3 \times 10^{-2} \times 10$

$= 30 \times 10^{-2}$ mol L^{-1}

4. **(c)** Rate of reaction can be defined as the change in concentration of a reactant or product in unit time. With respect to reactant, concentration decreases therefore, negative sign is used to express the rate. Whereas, with respect to product, concentration increases therefore, positive sign is used. For the given reaction,

$N_2 + 3H_2 \rightleftharpoons 2NH_3$

Rate of reaction is given as

$$-\frac{d[N_2]}{dt} = -\frac{1}{3}\frac{d[H_2]}{dt} = +\frac{1}{2}\frac{d[NH_3]}{dt}$$

5. **(d)** $2N_2O_5 \rightarrow 4NO_2 + O_2$

$$\text{Rate of reaction} = \frac{-1}{2}\frac{dN_2O_5}{dt} = \frac{1}{4}\frac{dNO_2}{dt} = \frac{dO_2}{dt}$$

Put the given values, in the above expression,

We get

$$\frac{1}{2}k[N_2O_5] = \frac{1}{4}k'[N_2O_5] = k''[N_2O_5]$$

Dividing above eq. with $[N_2O_5]$ and multiply with 4.

Therefore, we get $2k = k' = 4k''$

or

$k' = 2k$

$k'' = \frac{k}{2}$

6. **(c)** $N_2O_5(g) \rightarrow 2NO_2(g) + \frac{1}{2}O_2(g)$

Rate of disappearance of $N_2O_5(g)$ = Rate of appearance of NO_2 and $\frac{1}{2}O_2$

$$\frac{-d[N_2O_5]}{dt} = \frac{1}{2}\frac{d[NO_2]}{dt} = \frac{2d[O_2]}{dt} \quad \text{...(i)}$$

$$6.25\times10^{-3}\times2 = \frac{d[NO_2]}{dt} \quad \text{...(ii)}$$

$= 1.25 \times 10^{-2}$ mol$L^{-1}s^{-1}$

From eq. (i)

$$\frac{1}{2}\frac{d[NO_2]}{dt} = \frac{2d[O_2]}{dt}$$

From eq. (ii)

$$\frac{1}{4}\times1.25\times10^{-2} = \frac{d[O_2]}{dt}$$

$$\frac{d[O_2]}{dt} = 3.125 \times 10^{-3}\ \text{mol}L^{-1}s^{-1}$$

7. **(d)** According to rate of reaction

$$-\frac{1}{5}\frac{d[Br^-]}{dt} = +\frac{1}{3}\frac{d[Br_2]}{dt}$$

$$\frac{d[Br_2]}{dt} = \frac{-3}{5}\frac{d[Br^-]}{dt}$$

8. **(d)** According to rate of reaction

$$\frac{1}{2}\frac{d[NH_3]}{dt} = -\frac{1}{3}\frac{d[H_2]}{dt}$$

$$\frac{3}{2}\frac{d[NH_3]}{dt} = \frac{-d[H_2]}{dt}$$

$$\frac{3}{2}\times2\times10^{-4} = 3\times10^{-4}\,\text{mol}L^{-1}s^{-1}$$

9. **(b)** According to rate of reaction:

$$\frac{1}{2}\frac{d[NH_3]}{dt} = \frac{-1}{3}\frac{d[H_2]}{dt}$$

10. **(a)** Rate of reaction $= \frac{-1}{2}\frac{d[A]}{dt} = \frac{-d[B]}{dt} = \frac{1}{3}\frac{d[C]}{dt} = \frac{d[D]}{dt}$

Not, $\frac{-1}{3}\frac{d[C]}{dt}$

11. **(b)** $3A \rightarrow 2B$

$$\text{Rate of reaction} = \frac{1}{2}\frac{d[B]}{dt}$$

$$= \frac{-1}{3}\frac{d[A]}{dt}$$

$$\frac{d[B]}{dt} = -\frac{2}{3}\frac{d[A]}{dt}$$

12. **(a)** $-\frac{1}{3}\frac{d[Br^-]}{dt} = +\frac{1}{5}\frac{d[Br_2]}{dt}$ = rate of reaction

$$\Rightarrow \frac{d[Br^-]}{dt} = -\frac{3}{5}\frac{d[Br_2]}{dt}$$

13. **(b)** For $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$, the rate of reaction is $-\frac{\Delta[H_2]}{\Delta t} = -\frac{\Delta[I_2]}{\Delta t} = \frac{1}{2}\frac{\Delta[HI]}{\Delta t}$

Negative sign shows disappearance of reactant and positive sign shows the appearance of product.

14. **(d)** Let the new rate be, R'.

$A' = [3A]$, $B' = [B]$

$R' = K[A']^2[B']$

$= K[3A]^2[B]$

$= 9K[A]^2[B]$

$= 9 \times R$

Hence, rate would become nine times.

15. **(a)** For complex or multistep reactions, order is given b the slowest step.

In the slowest step.

$X + Y_2 \rightleftharpoons XY + Y$

half molecule of Y_2 reacts with the one molecule of X

$\therefore 1 + 0.5 = 1.5$

16. **(a)** Pressure of gas on metal/catalyst surface acts as concentration of reactant. Therefore, rate of reaction depends upon the pressure of the gas. At Low P, rate is proportional to the surface coverage and is of I^{st} order while at high P, it follows zero order due to complete coverage of surface area. (as at high pressure the surface of catalyst becomes saturated and thus pressure no longer affects the rate of reaction).

etc.

20. **(a)** According to the rate law

Rate = $k[A]^a[B]^b$

$$\frac{7.2\times10^{-2}}{2.88\times10^{-1}}=\frac{[0.3]^a[0.2]^b}{[0.3]^a[0.4]^b}$$

$$\frac{1}{4}=\frac{1}{(2)^b}$$

$b = 2$

$$\frac{6.0\times10^{-3}}{2.4\times10^{-2}}=\frac{[0.1]^a[0.1]^b}{[0.4]^a[0.1]^b}$$

$$\frac{1}{4}=\frac{1}{4^a}$$

$a = 1$

Rate = $k[A][B]^2$

21. **(a)** By doubling the initial concentration of A, rate doubles means it is a 1st order reaction with respect to A, by doubling the concentration of both (A and B) rate changes to 8 times, that is 2nd order with respect to B. The overall rate for reaction becomes

Rate = $k[A][B]^2$

22. **(b)** By comparing the rate and concentration, order of reaction can be calculated. Let rate of reaction wrt. $[CH_3COCH_3]$, $[Br_2]$ and $[H^+]$ are x, y and z

Thus,

Rate $\propto [CH_3COCH_3]^x [Br_2]^y [H^+]^z$

$5.7 \times 10^{-5} = [0.30]^x [0.05]^y [0.05]^z$ ...(i)

$5.7 \times 10^{-5} = [0.30]^x [0.10]^y [0.05]^z$ ...(ii)

$1.2 \times 10^{-4} = [0.30]^x [0.10]^y [0.10]^z$ ...(iii)

$3.1 \times 10^{-4} = [0.40]^x [0.05]^y [0.20]^z$ ...(iv)

from (i) and (ii)

$y = 0$

from (ii) and (iii)

$z = 1$

from (i) and (iv)

$x = 1$

Thus rate law, $r = k[CH_3COCH_3][H^+]$

$$\frac{r_2}{r_{1/4}}=\frac{k[A]^n[2B]^m}{k[A]^n[B]^m}$$

$$\frac{r_1}{r_{1/4}}=\frac{[B]^m}{2^m[B]^m}$$

$4 = 2^{-m}$

$2^2 = 2^{-m}$

$m = -2$

$2^y = (r_1/4)/r_1$

Thus $2^y = 1/4$

i.e. $y = -2$

Hence order w.r.t. [B] becomes –2

25. **(a)** $A \rightarrow$ Products

If $-\frac{dx}{dt}=k$,

It means $\frac{-dx}{dt}=k[A]^0=k$

Hence order is zero.

26. **(b)** $2A \rightarrow B + C$

The rate of reaction of this equation may be expresed as $r = k[A]^0$

$r = k$

27. **(b)** According to the unit of rate constant (which is sec^{-1} here) the order of reaction is 1. Therefore, According to rate law,

$\therefore$ rate = $k[N_2O_5]$;

$$[N_2O_5]=\frac{\text{rate}}{k}=\frac{1.02\times10^{-4}}{3.4\times10^{-5}}=3$$

28. **(c)** For the reaction $2A + B_2 \rightleftharpoons 2AB$ Rate $\propto [A]^x[B_2]^y$. On substituting the given data, we get

From experiment 1, $1.6 \times 10^{-4} \propto [0.50]^x[0.50]^y$ ...(i)

From experiment 2, $3.2 \times 10^{-4} \propto [0.50]^x[1.00]^y$ ...(ii)

From experiment 3, $3.2 \times 10^{-4} \propto [1.00]^x[1.00]^y$ ...(iii)

On dividing equation (iii) by (ii), we get $1=\left[\frac{1.00}{0.50}\right]^x$

or, $1 = 2^x$ or $2^1 = 2^x$ or $x = 0$ ..... (v)

On dividing equation (ii) by (i), we get

$2 = (2)^y$ i.e. $y = 1$

Thus rate equation is : Rate = $k[A]^0 [B_2]^1 = k[B_2]$

Keeping $[A]$ constant, $[B]$ is doubled, rate becomes 8 times.

Dividing Eq. (iii) by Eq. (i), we get

$$\frac{0.10}{0.10}=\left(\frac{0.024}{0.012}\right)^{x} \Rightarrow 2^{x}=1\ x=0.$$

Keeping $[B]$ constant, $[A]$ is doubled, rate remains unaffected.

Hence rate is independent of $[A]$. rate $\propto [B]^3$.

31. (c) Number of half lives, $(n)=\dfrac{t}{t_{1/2}}$

$$=\frac{8000}{2000}=4$$

$\therefore \quad n=4$

$$\frac{[A_0]}{[A_t]}=2^n$$

$[A_0]=[A_t]\times 2^n=0.02\times 2^4=0.32$ M

32. (c) A → Products

Initial conc, $[A_o]=0.1$ M

Concentration after 5 min $[A_t]=0.001$ M

t = 5 min.

For the given unit of rate constant (which is min^{-1}) the reaction is first order reaction

$$K=\frac{2.303}{t}\log\left(\frac{A_o}{A_t}\right)=\frac{2.303}{5}\log\left(\frac{0.1}{0.001}\right)$$

$K=0.9212\ min^{-1}$

33. (d)

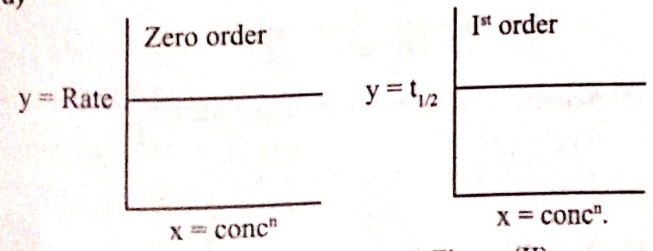


Figure (I) Figure (II)

Figure (I) is suitable for zero order if y = rate and x = concentration because in case of zero order reaction rate is constant and does not depend on $conc^n$.

Figure (II) is suitable for first order if $y = t_{1/2}$ and $x = conc^n$ because in case of first order $t_{1/2}$ does not depend on $conc^n$.

$$t_{1/2}=\frac{a}{2k}$$

$$k=\frac{a}{2t_{1/2}}$$

$$k=\frac{0.02}{2\times 100}=1\times 10^{-4}\ mol\ L^{-1}s^{-1}$$

36. (c) First order rate constant is given as,

$$k=\frac{2.303}{t}\log\frac{[A_0]}{[A]_t}$$

Where $[A_o]$ = Initial concentration

$[A_t]$ = Left concentration at time t

Here, $A_t = 100 - 99 = 1$

99% completion of reaction,

$$k=\frac{2.303}{t}\log\frac{100}{1}$$

$$k=\frac{2.303}{t}\times 2\log 10$$

$$t=\frac{2.303}{k}\times 2$$

$$t=\frac{4.606}{k}$$

37. (b) Half life for zero order reaction is given as,

$$\left(t_{1/2}\right)_{zero}=\frac{[A_o]}{2K} \qquad ...(i)$$

If initial concentration is doubled, the it becomes,

$$\left(t_{1/2}\right)'_{zero}=\frac{2[A_o]}{2K} \qquad ...(ii)$$

From (i) and (ii)

$$\left(t_{1/2}\right)'_{zero}=2\times\left(t_{1/2}\right)_{zero}$$

Hence, half life will be doubled on doubling the initial concentration.

38. (b)

- For first order reaction, $t_{1/2}=\dfrac{0.693}{k}$ which is independent of initial concentration of reactant.

* For second order reaction, $t_{1/2} = \frac{1}{k[A_0]}$, which depends on initial concentration of reactant.

39. (c) $k = 10^{-2}\ s^{-1}$, $t = ?$ $[R_0] = 20$ g

$[R] = 5$ g

$$t = \frac{2.303}{k}\log\frac{[R_0]}{[R]}$$

$$t = \frac{2.303}{10^{-2}}\log\frac{20}{5}$$

$t = 138.6$ sec

40. (b) For a first order reaction, A → products and for concentration of the reactant at two different times.

$$k = \frac{2.303}{t_2 - t_1}\log\frac{[A]_1}{[A]_2}$$

$$k = \frac{2.303}{t_2 - t_1}\log\frac{(rate)_1}{(rate)_2} \quad (\because rate \propto [A])$$

$$k = \frac{2.303}{(20-10)}\log\left(\frac{0.04}{0.03}\right) = 0.0287\ sec^{-1}$$

$$t_{1/2} = \frac{0.693}{k} = \frac{0.693}{0.0287\ sec^{-1}} = 24.14\ sec$$

41. (a) Reaction is of zero order as the unit of rate constant is mol L^{-1} s^{-1}.

$\therefore$ Concentration of B $= k \times t = 0.6 \times 10^{-3} \times 20 \times 60 = 0.72$ M

42. (a) Half life of Ist order reaction is independent of concentration of reactant. It is expressed as,

$$t_{1/2} = \frac{0.693}{k}\ sec$$

43. (a) Enzyme catalysed reactions follow first order kinetics

$\therefore$ Fall of concentration from 1.28 mg L^{-1} to 0.04 mg L^{-1} involves five half lives. It is expressed as,

$$1.28 \xrightarrow{t_{1/2}} 0.64 \xrightarrow{t_{1/2}} 0.32 \xrightarrow{t_{1/2}} 0.16 \xrightarrow{t_{1/2}} 0.08 \xrightarrow{t_{1/2}} 0.04$$

$\therefore$ Time required to complete the above process $= 5 \times t_{1/2}$

$= 5 \times 138$ s $= 690$ s

44. (b) According to 1st order reaction

$$t_{1/2} = \frac{0.693}{k}$$

$$k = \frac{0.693}{1386}$$

$$= 0.5 \times 10^{-3}\ s^{-1}$$

45. (a) For a first order reaction:

$$k = \frac{2.303}{t}\log\frac{a}{a-x}$$

When $t = 60$ and $x = 60\%$

$$k = \frac{2.303}{60}\log\frac{100}{100-60} = \frac{2.303}{60}\log\frac{100}{40}$$

Now,

$$t_{1/2} = \frac{2.303}{0.0153}\log\frac{100}{100-50} = \frac{2.303}{0.0153} \times \log 2$$

$$= \frac{2.303}{0.0153} \times 0.3010 = 45.31\ min.$$

46. (c) For a first order reaction

$$k = \frac{2.303}{t}\log_{10}\left(\frac{a}{a-x}\right)$$

When $t = t_{1/2}$

$$k = \frac{2.303}{t_{1/2}}\log_{10}\left(\frac{a}{a-x}\right)$$

or $t_{1/2} = \frac{2.303}{k}\log_{10} 2 = \frac{\ln 2}{k}$

47. (d) For 1st order reaction $K = \frac{0.693}{t_{1/2}}$

$$t_{1/2} = \frac{0.693}{2 \times 10^{-3}} = 347\ sec$$

48. (a)

In Case I		In Case II	
A → B		A → B	
0.8 → 0		0.9 → 0	
0.2	0.6	0.225	0.675
1	3	1	3

The time taken for the completion of same fraction of change is independent of initial concentration.

49. (b) $T = t_{1/2} \times n$

Where T = Total time

$t_{1/2}$ = half life

n = No. of half lives

$$n = \frac{49.2}{12.3} = 4$$

Amount of tritium (in mg) left after 49.2 year is calculated as.

$N = N_0\left(\frac{1}{2}\right)^n$ where,

N = left amount

N_0 = Initial amount

$$N = N_0\left(\frac{1}{2}\right)^n = 32\left(\frac{1}{2}\right)^4$$

$$= 32 \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = 2\ mg$$

50. (c) At the end of 24 hrs. activity = 0.01 M

Half life = 6 hrs

In 24 hrs. there are $\frac{24}{6} = 4$ half lifes.

Activity of substance after n half life $= \frac{(A)}{2^n}$

$$= \frac{(A)}{2^4} = 0.01 = 0.16$$

51. (a) $t_{1/2}$ of nth order $\propto \frac{1}{a^{n-1}}$

When = n = 1

$$t_{1/2} \propto \frac{1}{a^{1-1}} \propto \frac{1}{a^0}$$

So for first order reaction half life is independent of initial concentration of reactant

52. (b) Radioactive decay follows first order reaction process therefore it is expressed as,

$$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$$

$$t_{\frac{1}{2}} = \frac{0.693}{2.31\times10^{-4}}\ \text{yr}$$

$$\Rightarrow 3\times10^{3}\ \text{yr.}$$

53. (c) A reaction can have zero activation energy, for example, $\dot{C}H_3 + \dot{C}H_3 \rightarrow CH_3{-}CH_3$ has zero activation energy.

54. (a) $\Delta H_{rxn} = E_{a_{(forward)}} - E_{a_{(backward)}}$

$$-4.2 = (E_{a_{(forward)}} - E_{a_{(backward)}})$$

$$-4.2 = 9.6 - (E_a)_{backward}$$

$$E_{a_{(backward)}} = 9.6 + 4.2 = 13.8\ \text{kJ mol}^{-1}$$

Activation energy of backward reaction is more than that of forward reaction.

Thus reaction is exothermic.

55. (d) According to Arhenius equation:

$$K = Ae^{-E_a/RT}$$

$$\ln K = \ln A - \frac{E_a}{RT}$$

Slope of (ln k v/s 1/T) curve,

$$m = -\frac{E_a}{R}$$

$$-5\times10^{3} = -\frac{E_a}{R}$$

$$E_a = 5\times10^{3}\times8.314\ \text{J/mol}$$

$$= 41.57\times103\ \text{J/mol}$$

$$\simeq 41.5\ \text{kJ/mol}$$

56. (a) When we add catalysts to any chemical reaction. It provides an alternative pathway for the reaction and lowers the activation energy. So the reaction becomes fast. As E_f and E_b (activation energy for forward and backward reaction) is reduced to same extent, so there is no change in enthalpy of reaction.

57. (b) According to Arrhenius equation:

$$k = A^{e^{-E_a/RT}}$$

$$\ln k = \ln A - \frac{E_a}{RT}$$

Comparing with straight line equation $y = c + Mx$

Slope will be $-E_a/R$

58. (c) Enthalpy(ΔH) = E_f activation energy of forward − E_b activation energy of backward reaction

When $E_f = E_b$

$\Delta H = 0$

59. (c) $\log\frac{k_2}{k_1} = \frac{E_a}{2.303R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$

$k_2 = 2k_1$, $T_1 = 20 + 273 = 293$ K

or $T_2 = 35 + 273 = 308$ K

$R = 8.314\ \text{J mol}^{-1}\ \text{K}^{-1}$

$$\log 2 = \frac{E_a}{2.303\times8.314}\left(\frac{1}{293} - \frac{1}{308}\right)$$

$$0.3010 = \frac{E_a}{19.147}\times\frac{15}{293\times308}$$

$$E_a = 34673\ \text{J mol}^{-1} \text{ or } 34.7\ \text{kJ mol}^{-1}$$

60. (c) $k_1 = Ae^{-E_a/RT_1}, k_2 = Ae^{-E_a/RT_2}$

$$\ln k_1 = \ln A - E_a/RT_1 \quad \text{....(i)}$$

$$\ln k_2 = \ln A - E_a/RT_2 \quad \text{....(ii)}$$

From eq. (i) and (ii), we have

$$\ln k_2 - \ln k_1 = \ln A - \frac{E_a}{RT_2} - \ln A + \frac{E_a}{RT_1}$$

$$\Rightarrow \ln\frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$\Rightarrow \ln\frac{k_2}{k_1} = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

61. (c) For 10° rise is temperature, n = 1

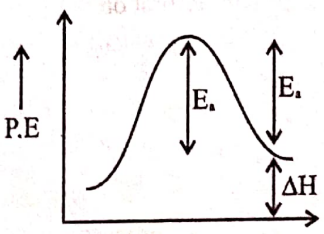
So rate = $2^n = 2^1 = 2$

When temperature is increased from 10° to 100°C change in temperature = 100 − 10 = 90°C i.e.

n = 9, so, rate = $2^9 = 512$

62. (a) Only way to increase the value of rate constant (k) is by increasing temperature, as we know that for a chemical reaction with rise in temperature by 10 degree the rate constant is nearly doubled.

63. (d) In endothermic reactions, the energy of reactants is less than that of products. Potential energy diagram for endothermic reaction is



Progress of reactions

$E_a = E_a + \Delta H$

Thus $E_a > \Delta H$

64. (a) $k_1 = 10^{16}e^{-2000/T}$, $k_2 = 10^{15}e^{-1000/T}$

The temperature at which $k_1 = k_2$ will be

$$10^{16}e^{-2000/T} = 10^{15}e^{-1000/T}$$

$$\Rightarrow \frac{e^{-2000/T}}{e^{-1000/T}} = \frac{10^{15}}{10^{16}}$$

$$\Rightarrow e^{\frac{-1000}{T}} = 10^{-1} \Rightarrow \log_e e^{\frac{-1000/T}{T}} = \log_e 10^{-1}$$

$$\Rightarrow 2.303\log_{10}e^{\frac{-1000}{T}} = 2.303\times\log_{10}10^{-1}$$

$$\Rightarrow \frac{-1000}{T}\times\log_{10}e = -1 \therefore T = \frac{1000}{2.303}\text{K}$$

where K_1 and K_2 = rate constant at two different temperature

E_a = Activation energy

R = Gas constant

So, activation energy of a chemical reaction can be determine by evaluating rate constant at two different temperatures.

energy

Collision frequency ∝ no. of reacting molecules or

Higher the concentration of reactant molecules, hig

probability of collisions and so the collision freque

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1. Which of the following reactions is a part of the large scale industrial preparation of nitric acid *(2022 Re)*

a. $Cu(NO_3)_2 + 2NO_2 + 2H_2O \xrightarrow[500\ K,\ 9\ bar]{Pt} 4HNO_3 + Cu$

b. $NaNO_3 + H_2SO_4 \xrightarrow[500\ K,9\ bar]{Pt} NaHSO_4 + HNO_3$

c. $4NH_3 + 5O_2$ (from air) $\xrightarrow[500\ K,9\ bar]{Pt} 4NO + 6H_2O$

d. $4HPO_3 + 2N_2O_5 \xrightarrow[500\ K,9\ bar]{Pt} 4HNO_3 + P_4O_{10}$

2. Urea reacts with water to form A which will decompose to form B. B when passed through Cu^{2+} (aq), deep blue colour solution C is formed. What is the formula of C from the following? *(2020)*

a. $[Cu(NH_3)_4]^{2+}$ b. $Cu(OH)_2$

c. $CuCO_3.Cu(OH)_2$ d. $CuSO_4$

3. Among the compounds shown below which one revealed a linear structure? *(2020-Covid)*

a. HOCl b. O_3

c. N_2O d. NO_2

4. Match the following: *(2019)*

	Column-I		Column-II
A.	Pure nitrogen	i.	Chlorine
B.	Haber process	ii.	Sulphuric acid
C.	Contact process	iii.	Ammonia
D.	Deacon's process	iv.	Sodium azide or Barium azide

Which of the following is the correct option?

	A	B	C	D
a.	i	ii	iii	iv
b.	ii	iv	i	iii
c.	iii	iv	ii	i
d.	iv	iii	ii	i

5. The correct order of N-compounds in its decreasing order of oxidation states is *(2018)*

a. HNO_3, NO, N_2, NH_4Cl b. HNO_3, NO, NH_4Cl, N_2

c. NH_4Cl, N_2, NO, HNO_3 d. HNO_3, NH_4Cl, NO, N_2

a monoprotic acid.

b. Phosphinic acid is a monoprotic acid while phosphonic acid is a diprotic acid

c. Both are diprotic acids

d. Both are triprotic acids

7. When copper is heated with conc. HNO_3 it produces: *(2016 - I)*

a. $Cu(NO_3)_2$ and N_2O b. $Cu(NO_3)_2$ and NO_2

c. $Cu(NO_3)_2$ and NO d. $Cu(NO_3)_2$, NO and NO_2

8. Strong reducing behaviour of H_3PO_2 is due to: *(2015 Re)*

a. Presence of two –OH groups and one P – H bond

b. Presence of one –OH group and two P – H bonds

c. High electron gain enthalpy of phosphorus

d. High oxidation state of phosphorus

9. Nitrogen dioxide and sulphur dioxide have some properties in common. Which property is shown by one of these compounds, but not by the other? *(2015)*

a. Is soluble in water

b. Is used as a food preservative

c. Forms 'acid-rain'

d. Is a reducing agent

10. Which of the following does not give oxygen on heating? *(2013)*

a. $KClO_3$ b. $Zn(ClO_3)_2$

c. $K_2Cr_2O_7$ d. $(NH_4)_2Cr_2O_7$

11. Which of the following statements is not valid for oxoacids of phosphorus? **[MR*]** *(2012 Pre)*

a. All oxoacids contain atleast one P = O unit and one P – OH group

b. Orthophosphoric acid is used in the manufacture of triple superphosphate.

c. Hypophosphorous acid is a diprotic acid.

d. All oxoacids contain tetrahedral four coordinated phosphorous

12. How many bridging oxygen atoms are present in P_4O_{10}? *(2010 Mains)*

a. 6 b. 4

c. 2 d. 5

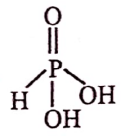
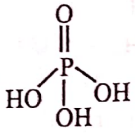
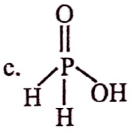
13. Oxidation states of P in $H_4P_2O_5$, $H_4P_2O_6$, $H_4P_2O_7$ are respectively *(2010 Pre)*
a. +3, +5, +4 b. +5, +3, +4
c. +5, +4, +3 d. +3, +4, +5

14. Which of the following is the most basic oxide? *(2006)*
a. Al_2O_3 b. Sb_2O_3
c. Bi_2O_3 d. SeO_2

15. Which of the following is most acidic? *(1999)*
a. N_2O_5 b. P_2O_5
c. As_2O_5 d. Sb_2O_5

16. Which of the following phosphorus is the most reactive? *(1999)*
a. Red phosphorus b. White phosphorus
c. Scarlet phosphorus d. Violet phosphorus

17. Which of the following has the highest dipole moment? *(1997)*
a. SbH_3 b. AsH_3
c. NH_3 d. PH_3

18. The structural formula of hypophosphorous acid is: *(1997)*
a. 
b. 
c. 
d. None of these

19. The basic character of hydrides of the V group elements decreases in the order: [MR*] *(1996)*
a. $NH_3 > PH_3 > AsH_3 > SbH_3$
b. $SbH_3 > AsH_3 > PH_3 > NH_3$
c. $SbH_3 > PH_3 > AsH_3 > NH_3$
d. $NH_3 > SbH_3 > PH_3 > AsH_3$

20. Among the following oxides, the least acidic is: *(1996)*
a. As_4O_6 b. As_4O_{10}
c. P_4O_6 d. P_4O_{10}

21. Which of the following oxides of nitrogen is paramagnetic? *(1994)*
a. NO_2 b. N_2O_3
c. N_2O d. N_2O_5

22. Which of the following fluorides does not exist? *(1993)*
a. NF_5 b. PF_5
c. AsF_5 d. SbF_5

23. Which one of the following substance is used in the laboratory for fast drying of neutral gases? *(1992)*
a. Phosphorus pentoxide
b. Active charcoal
c. Anhydrous calcium chloride
d. Na_3PO_4

24. Number of electrons shared in the formation of molecule is: *(1992)*
a. 6 b. 10
c. 2 d. 8

25. Sugarcane on reaction with nitric acid gives: *(1992)*
a. CO_2 and SO_2 b. $(COOH)_2$
c. 2HCOOH(two moles) d. No reaction

26. Nitrogen is relatively inactive element because: *(1992)*
a. Its atom has a stable electronic configuration
b. It has low atomic radius
c. Its electronegativity is fairly high
d. Dissociation energy of its molecule is fairly high

27. H_3PO_2 is the molecular formula of an acid of phosphorus. Its name and basicity respectively are: *(1992)*
a. Phosphorous acid and two
b. Hypophosphorous acid and two
c. Hypophosphorous acid and one
d. Hypophosphoric acid and two

28. Aqueous solution of ammonia consists of: *(1991)*
a. H^+ b. OH^-
c. NH_4^+ d. NH_4^+ and OH^-

29. P_2O_5 is heated with water to give: *(1991)*
a. Hypophosphorous acid
b. Phosphorous acid
c. Hypophosphoric acid
d. Orthophosphoric acid

30. Basicity of orthophosphoric acid is: *(1991)*
a. 2 b. 3
c. 4 d. 5

31. PCl_3 reacts with water to form: *(1991)*
a. PH_3 b. H_3PO_3, HCl
c. $POCl_3$ d. H_3PO_4

32. $PH_4I + NaOH$ forms: *(1991)*
a. PH_3 b. NH_3
c. P_4O_6 d. P_4O_{10}

33. Pure nitrogen is prepared in the laboratory by heating a mixture of: *(1991)*
a. $NH_4OH + NaCl$ b. $NH_4NO_3 + NaCl$
c. $NH_4Cl + NaOH$ d. $NH_4Cl + NaNO_2$

34. Which of the following statement is not correct for nitrogen? *(1990)*
a. Its electronegativity is very high.
b. *d*-orbitals are available for bonding.
c. It is a typical non-metal.
d. Its molecular size is small.

35. Which of the following compound does not exist? *(1989)*
a. NCl_5 b. AsF_5
c. $SbCl_5$ d. PF_5

36. Each of the following is true for white and red phosphorus except that they: *(1989)*
a. Are both soluble in CS_2
b. Can be oxidised by heating in air
c. Consist of the same kind of atoms
d. Can be converted into one another.

37. When orthophosphoric acid is heated to 600°C, the product formed is: *(1989)*
a. PH_3 b. P_2O_5
c. H_3PO_3 d. HPO_3

38. Which one has the lowest boiling point? *(1989)*
a. NH_3 b. PH_3
c. AsH_3 d. SbH_3

39. Which of the following is a nitric acid anhydride? *(1988)*
a. NO b. NO_2
c. N_2O_5 d. N_2O_3

Group 16 Elements (Oxygen Family)

40. Amongst the given options, which of the following molecules/ion acts as a Lewis acid? *(2023)*
a. OH^- b. NH_3
c. H_2O d. BF_3

41. Match List-I with List-II: [MR*] *(2023)*

	List-I (Oxoacids of Sulphur)		List-II (Bonds of Sulphur)
A.	Peroxodisulphuric acid	I.	Two S-OH, Four S=O, One S-O-S
B.	Sulphuric acid	II.	Two S-OH, One S=O
C.	Pyrosulphuric acid	III.	Two S-OH, Four S=O,One S-O-O-S
D.	Sulphurous acid	IV.	Two S-OH, Two S=O

Choose the correct answer from the options given below :
a. A-III, B-IV, C-II, D-I b. A-I, B-III, C-II, D-IV
c. A-III, B-IV, C-I, D-II d. A-I, B-III, C-IV, D-II

42. Given below are two statements: *(2022)*
Statement-I: The boiling points of the following hydrides of group 16 elements increases in the order-
$H_2O < H_2S < H_2Se < H_2Te$.
Statement-II: The boiling points of these hydrides increase with increase in molar mass.
In the light of the above statements, choose the **most appropriate** answer from the options given below:
a. Statements-I is incorrect but Statements-II is correct.
b. Both Statements-I and Statements-II are correct
c. Both Statements-I and Statements-II are incorrect
d. Statements-I is correct but Statements-II is incorrect

43. In which one of the following arrangements the given sequence is not strictly according to the properties indicated against it? *(2021)*
a. $H_2O < H_2S < H_2Se < H_2Te$: Increasing pK_a values
b. $NH_3 < PH_3 < AsH_3 < SbH_3$: Increasing acidic character
c. $CO_2 < SiO_2 < SnO_2 < PbO_2$: Increasing oxidizing power
d. $HF < HCl < HBr < HI$: Increasing acidic strength

44. Which of the following oxoacid of sulphur has – O – O – linkage? *(2020)*
a. H_2SO_4, sulphuric acid
b. $H_2S_2O_8$, peroxodisulphuric acid
c. $H_2S_2O_7$, pyrosulphuric acid
d. H_2SO_3, sulphurous acid

45. The reaction of concentrated sulphuric acid with carbohydrates ($C_{12}H_{12}O_{11}$) is an example of *(2020-Covid)*
a. Oxidation b. Reduction
c. Sulphonation d. Dehydration

46. Which is the correct thermal stability order for H_2E (E = O, S, Se, Te and Po)? [MR*] *(2019)*
a. $H_2S < H_2O < H_2Se < H_2Te < H_2Po$
b. $H_2O < H_2S < H_2Se < H_2Te < H_2Po$
c. $H_2Po < H_2Te < H_2Se < H_2S < H_2O$
d. $H_2Se < H_2Te < H_2Po < H_2O < H_2S$

47. In which pair of ions both the species contain S – S bond? [MR*] *(2017-Delhi)*
a. $S_4O_6^{2-}, S_2O_7^{2-}$ b. $S_2O_7^{2-}, S_2O_3^{2-}$
c. $S_4O_6^{2-}, S_2O_3^{2-}$ d. $S_2O_7^{2-}, S_2O_8^{2-}$

48. Which of the statements given below is incorrect? *(2015 Re)*
a. O_3 molecule is bent
b. ONF is isoelectronic with O_2N^-
c. OF_2 is an oxide of fluorine
d. Cl_2O_7 is an anhydride of perchloric acid

49. Acidity of diprotic acids in aqueous solutions increases in the order: *(2014)*
a. $H_2Se < H_2S < H_2Te$ b. $H_2Te < H_2S < H_2Se$
c. $H_2Se < H_2Te < H_2S$ d. $H_2S < H_2Se < H_2Te$

50. In which of the following arrangements the given sequence is not strictly according to the property indicated against it? [MR*] *(2012 Mains)*
a. $CO_2 < SiO_2 < SnO_2 < PbO_2$: increasing oxidising power
b. $HF < HCl < HBr < HI$: increasing acidic strength
c. $H_2O < H_2S < H_2Se < H_2Te$: increasing pK_a values
d. $NH_3 < PH_3 < AsH_3 < SbH_3$: increasing acidic character

51. Sulphur trioxide can be obtained by which of the following reaction? *(2012 Pre)*
a. $CaSO_4 + C \xrightarrow{\Delta}$ b. $Fe_2(SO_4)_3 \xrightarrow{\Delta}$
c. $S + H_2SO_4 \xrightarrow{\Delta}$ d. $H_2SO_4 + PCl_5 \xrightarrow{\Delta}$

52. Match List-I (substances) with List-II (process) employed in the manufacture of the substances and select the correct option: *(2010 Mains)*

	List-I Substances		List-II Processes
A.	Sulphuric acid	(i)	Haber's Process
B.	Steel	(ii)	Bessemer's Process
C.	Sodium hydroxide	(iii)	Leblanc Process
D.	Ammonia	(iv)	Contact Process

a. A(i), B(iv), C(ii), D(iii)
b. A(i), B(ii), C(iii), D(iv)
c. A(iv), B(iii), C(ii), D(i)
d. A(iv), B(ii), C(iii), D(i)

53. The angular shape of ozone molecule (O_3) consists of: *(2008)*

a. 1 σ and 1π bond
b. 2 σ and 1π bond
c. 1 σ and 2π bond
d. 2 σ and 2π bond

54. What is the correct relationship between the pH of isomolar solutions of sodium oxide, Na_2O (pH_1), sodium sulphide, Na_2S (pH_2), sodium selenide, Na_2Se (pH_3) and sodium telluride Na_2Te (pH_4)? *(2005)*

a. $pH_1 > pH_2 > pH_3 > pH_4$
b. $pH_1 > pH_2 \approx pH_3 > pH_4$
c. $pH_1 < pH_2 < pH_3 < pH_4$
d. $pH_1 < pH_2 < pH_3 \approx pH_4$

55. The oxidation states of sulphur in the anions SO_3^{2-}, $S_2O_4^{2-}$ and $S_2O_6^{2-}$ follow the order: *(2003)*

a. $S_2O_4^{2-} < SO_3^{2-} < S_2O_6^{2-}$
b. $SO_3^{2-} < S_2O_4^{2-} < S_2O_6^{2-}$
c. $S_2O_4^{2-} < S_2O_6^{2-} < SO_3^{2-}$
d. $S_2O_6^{2-} < S_2O_4^{2-} < SO_3^{2-}$

56. Which of the following bonds has the highest energy? *(1996)*

a. S–S
b. O–O
c. Se–Se
d. Te–Te

57. Reaction of sodium thiosulphate with iodine gives: **[OS]** *(1996)*

a. Tetrathionate ion
b. Sulphide ion
c. Sulphate ion
d. Sulphite ion

58. About 20 km above the earth, there is an ozone layer. Which one of the following statements about ozone and ozone layer is true? *(1995)*

a. It is beneficial to us as it stops U.V. radiation
b. Conversion of O_3 to O_2 is an endothermic reaction
c. Ozone has a triatomic linear molecule
d. It is harmful as it stops useful radiation

59. Which would quickly absorb oxygen? *(1991)*

a. Alkaline solution of pyrogallol
b. Conc. H_2SO_4
c. Lime water
d. Alkaline solution of $CuSO_4$

60. Oleum is: *(1991)*

a. Castor oil
b. Oil of vitriol
c. Fuming H_2SO_4
d. None of these

61. The gases respectively absorbed by alkaline pyrogallol and oil of cinnamon are:

a. O_3, CH_4
b. O_2, O_3
c. SO_2, CH_4
d. N_2O, O_3

62. It is possible to obtain oxygen from air by fractional distillation because:

a. Oxygen is in a different group of the periodic table from nitrogen
b. Oxygen is more reactive than nitrogen
c. Oxygen has higher boiling point than nitrogen
d. Oxygen has a lower density than nitrogen.

Group 17 Elements (Halogens)

63. Fluorine is a stronger oxidising agent than chlorine because:

(a) F-F bond has a low enthalpy of dissociation.
(b) Fluoride ion (F^-) has high hydration enthalpy.
(c) Electron gain enthalpy of flourine is less negative than chlorine.
(d) Fluorine has a very small size.

Choose the **most appropriate** answer from the options given: *(2022 Re)*

a. (b) and (c) only
b. (a) and (b) only
c. (a) and (c) only
d. (a) and (d) only

64. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R) *(2022)*

Assertion (A): ICl is more reactive than I_2.

Reason (R): I-Cl bond is weaker than I-I bond

In the light of the above statements, choose the most appropriate answer from the options given below:

a. (A) is not correct but (R) is correct.
b. Both (A) and (R) are correct and (R) is the correct explanation of (A).
c. Both (A) and (R) are correct but (R) is not the correct explanation of (A).
d. (A) is correct but (R) is not correct.

65. **Statement-I:** Acid strength increases in the order given as HF << HCl << HBr << HI. *(2021)*

Statement-II: As the size of the elements F, Cl, Br, I increases down the group, the bond strength of HF, HCl, HBr and HI decreases and so the acid strength increases.

In the light of the above statements, choose the correct answer from the options given below.

a. Both Statement-I and Statement-II are false
b. Statement-I in correct but Statement-II is false
c. Statement-I is incorrect but Statement-II is true
d. Both Statement-I and Statement-II are true

66. Which one of the following reactions does not come under hydrolysis type reaction? *(2020-Covid)*

a. $Li_3N(s) + 3H_2O(l) \rightarrow NH_3(s) + 3LiOH(aq)$
b. $2F_2(g) + 2H_2O(l) \rightarrow 4HF(aq) + O_2(g)$
c. $P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$
d. $SiCl_4(l) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl(aq)$

67. Which of the following statements is not true for halogens? *(2018)*

a. All form monobasic oxyacids
b. All are oxidizing agents
c. Chlorine has the highest electron-gain enthalpy
d. All but fluorine show positive oxidation states

68. In the structure of ClF_3, the number of lone pair of electrons on central atom 'Cl' is *(2018)*

a. One b. Two
c. Three d. Four

69. Match the interhalogen compounds of Column-I with the geometry in Column-II and assign the correct code: **[MR*]** *(2017-Delhi)*

	Column-I		Column-II
(A)	XX'	(i)	T–shape
(B)	XX'_3	(ii)	Pentagonal bipyramidal
(C)	XX'_5	(iii)	Linear
(D)	XX'_7	(iv)	Square–pyramidal
		(v)	Tetrahedral

Code:

	(A)	(B)	(C)	(D)
a.	(iv)	(iii)	(ii)	(i)
b.	(iii)	(iv)	(i)	(ii)
c.	(iii)	(i)	(iv)	(ii)
d.	(v)	(iv)	(iii)	(ii)

70. Which one of the following orders is correct for the bond dissociation enthalpy of halogen molecules? *(2016 - I)*

a. $F_2 > Cl_2 > Br_2 > I_2$ b. $I_2 > Br_2 > Cl_2 > F_2$
c. $Cl_2 > Br_2 > F_2 > I_2$ d. $Br_2 > I_2 > F_2 > Cl_2$

71. Among the following, the correct order of acidity is: *(2016 - I)*

a. $HClO_4 < HClO_2 < HClO < HClO_3$
b. $HClO_3 < HClO_4 < HClO_2 < HClO$
c. $HClO < HClO_2 < HClO_3 < HClO_4$
d. $HClO_2 < HClO < HClO_3 < HClO_4$

72. The variation of the boiling points of the hydrogen halides is in the order HF > HI > HBr > HCl. What explains the higher boiling point of hydrogen fluoride? *(2015 Re)*

a. The effect of nuclear shielding is much reduced in fluorine which polarizes the HF molecule
b. The electronegativity of fluorine is much higher than for other elements in the group
c. There is strong hydrogen bonding between HF molecules
d. The bond energy of HF molecules is greater than in other hydrogen halides

73. Which is the strongest acid in the following? *(2013)*

a. H_2SO_4 b. $HClO_3$
c. $HClO_4$ d. H_2SO_3

74. When Cl_2 gas reacts with hot and concentrated sodium hydroxide solution, the oxidation number of chlorine changes from: *(2012 Pre)*

a. Zero to + 1 and zero to –3
b. Zero to +1 and zero to –5
c. Zero to –1 and zero to + 5
d. Zero –1 and zero to + 3

75. Which one of the following arrangements does not give the correct picture of the trends indicated against it? *(2008)*

a. $F_2 > Cl_2 > Br_2 > I_2$: Electronegativity
b. $F_2 > Cl_2 > Br_2 > I_2$: Oxidizing power
c. $F_2 > Cl_2 > Br_2 > I_2$: Electron gain enthalpy
d. $F_2 > Cl_2 > Br_2 > I_2$: Bond dissociation energy

76. Which one of the following orders correctly represents the increasing acid strengths of the given acids? **[MR*]** *(2007, 2005)*

a. $HOClO < HOCl < HOClO_3 < HOClO_2$
b. $HOClO_2 < HOClO_3 < HOClO < HOCl$
c. $HOClO_3 < HOClO_2 < HOClO < HOCl$
d. $HOCl < HOClO < HOClO_2 < HOClO_3$

77. Which one of the following orders is not in accordance with the property stated against it? **[MR*]** *(2006)*

a. $F_2 > Cl_2 > Br_2 > I_2$: Oxidising power
b. HI > HBr > HCl > HF : Acidic property in water
c. $F_2 > Cl_2 > Br_2 > I_2$: Electronegativity
d. $F_2 > Cl_2 > Br_2 > I_2$: Bond dissociation energy

78. The correct order of acid strength is: *(2005)*

a. $HClO < HClO_2 < HClO_3 < HClO_4$
b. $HClO_4 < HClO < HClO_2 < HClO_3$
c. $HClO_2 < HClO_3 < HClO_4 < HClO$
d. $HClO_4 < HClO_3 < HClO_2 < HClO$

79. Which of the following statement is true? *(2002)*

a. Silicon exhibits 4 coordination number in its compound
b. Bond energy of F_2 is less than Cl_2
c. Mn(III) oxidation state is more stable than Mn(II) in aqueous state
d. Elements of 15th group shows only + 3 and + 5 oxidation states

80. Which of the following elements has maximum electron affinity? **[MR*]** *(1999)*

a. Cl b. Br
c. I d. F

81. A one litre flask is full of brown bromine vapour. The intensity of brown colour of vapour will not decrease appreciably on adding to the flask some: *(1998)*

a. Pieces of marble b. Animal charcoal powder
c. Carbon tetrachloride d. Carbon disulphide

82. Which of the following has the greatest electron affinity? *(1996)*

a. I b. Br
c. F d. Cl

83. Which of the following represents calcium chlorite? *(1996)*

a. $Ca(ClO_3)_2$ b. $Ca(ClO_2)_2$
c. $CaClO_2$ d. $Ca(ClO_4)_2$

84. Which of the following displaces Br_2 from an aqueous solution containing bromide ions? *(1994)*

a. I_2 b. I_3^-
c. Cl_2 d. Cl^-

85. Which of the following species has four lone pairs of electrons? *(1993)*

a. I b. O
c. Cl^- d. He

86. A solution of potassium bromide is treated with each of the following. Which one would liberate bromine? **[MR*]** *(1993)*

a. Hydrogen iodide b. Sulphur dioxide
c. Chlorine d. Iodine

87. Which of the following elements is extracted commercially by the electrolysis of an aqueous solution of its compound? *(1993)*

a. Cl b. Br
c. Al d. Na

88. Which of the following sets has strongest tendency to form anions? *(1993)*

a. Ga, Ni, Tl b. Na, Mg, Al
c. N, O, F d. V, Cr, Mn

89. Which of the following bonds will be most polar? *(1992)*

a. N – Cl b. O – F
c. N – F d. N – N

90. Elements of which of the following groups will form anions most readily? *(1992)*

a. Oxygen family b. Nitrogen family
c. Halogens d. Alkali metals

91. Strongest hydrogen bonding is shown by: *(1992)*

a. Water b. Ammonia
c. Hydrogen fluoride d. Hydrogen sulphide

92. When chlorine is passed over dry slaked lime at room temperature, the main reaction product is: *(1992)*

a. $Ca(ClO_2)_2$ b. $CaCl_2$
c. $CaOCl_2$ d. $Ca(OCl)_2$

93. In the manufacture of bromine from sea water, the mother liquor containing bromides is treated with: *(1992)*

a. Carbon dioxide b. Chlorine
c. Iodine d. Sulphur dioxide

94. The bleaching action of chlorine is due to: *(1991)*

a. Reduction b. Hydrogenation
c. Chlorination d. Oxidation

95. Oxygen will directly react with each of the following elements except: *(1989)*

a. P b. Cl
c. Na d. S

96. Bleaching powder reacts with a few drops of concentration HCl to give: *(1989)*

a. Chlorine b. Hypochlorous acid
c. Calcium oxide d. Oxygen

Group 18 Elements (Noble Gases)

97. Noble gases are named because of their inertness towards reactivity. Identify an incorrect statement about them. *(2021)*

a. Noble gases have very high melting and boiling points
b. Noble gases have weak dispersion forces
c. Noble gases have large positive values of electron gain enthalpy
d. Noble gases are sparingly soluble in water

98. Match the compounds of Xe in Column-I with the molecular structure in Column-II. *(2020-Covid)*

	Column-I		Column-II
(A)	XeF_2	(i)	Square planar
(B)	XeF_4	(ii)	Linear
(C)	XeO_3	(iii)	Square pyramidal
(D)	$XeOF_4$	(iv)	Pyramidal

a. A-ii B-i C-iv D-iii
b. A-ii B-i C-iii D-iv
c. A-ii B-iv C-iii D-i
d. A-ii B-iii C-i D-iv

99. Match the Xenon compounds in Column-I with its structure in Column-II and assign the correct code: **[MR*]** *(2019)*

	Column-I		Column-II
(A)	XeF_4	(i)	Pyramidal
(B)	XeF_6	(ii)	Square planar
(C)	$XeOF_4$	(iii)	Distorted octahedral
(D)	XeO_3	(iv)	Square pyramidal

Code:

	A	B	C	D
a.	i	ii	iii	iv
b.	ii	iii	iv	i
c.	ii	iii	i	iv
d.	iii	iv	i	ii

100. Which of the following pairs of compounds is isoelectronic and isostructural? **[MR*]** *(2017-Delhi)*

a. IF_3, XeF_2 b. $BeCl_2$, XeF_2
c. TeI_2, XeF_2 d. IBr_2^-, XeF_2

101. The correct geometry and hybridization for XeF_4 are: *(2016 - II)*

a. Planar triangle, sp^3d^3
b. Square planar, sp^3d^2
c. Octahedral, sp^3d^2
d. Trigonal bipyramidal, sp^3d

102. Match the compound given in Column-I with the hybridization and shape given in Column-II and mark the correct option. *(2016 - I)*

	Column-I		Column-II
(A)	XeF_6	(i)	Distorted octahedral
(B)	XeO_3	(ii)	Square planar
(C)	$XeOF_4$	(iii)	Pyramidal
(D)	XeF_4	(iv)	Square pyramidal

Code:

	(A)	(B)	(C)	(D)
a.	(iv)	(i)	(ii)	(iii)
b.	(i)	(iii)	(iv)	(ii)
c.	(i)	(ii)	(iv)	(iii)
d.	(iv)	(iii)	(i)	(ii)

103. In which of the following pairs, both the species are not isostructural? *(2015 Re)*

a. XeF_4, XeO_4
b. $SiCl_4$, PCl_4^+
c. Diamond, silicon carbide
d. NH_3, PH_3

104. XeF_2 is isostructural with: *(2013)*

a. TeF_2 b. ICl_2^-
c. $SbCl_3$ d. $BaCl_2$

105. Which compound has planar structure? *(2000)*

a. XeF_4 b. $XeOF_2$
c. XeO_2F_2 d. XeO_4

Team Kohinoor
TgI'd - @kohinooroffical1

Answer Key

1. (c)	2. (a)	3. (c)	4. (d)	5. (a)	6. (b)	7. (b)	8. (b)	9. (b)	10. (d)
11. (c)	12. (a)	13. (d)	14. (c)	15. (a)	16. (b)	17. (c)	18. (c)	19. (a)	20. (a)
21. (a)	22. (a)	23. (a)	24. (a)	25. (b)	26. (d)	27. (c)	28. (d)	29. (d)	30. (b)
31. (b)	32. (a)	33. (d)	34. (b)	35. (a)	36. (a)	37. (d)	38. (b)	39. (c)	40. (d)
41. (c)	42. (c)	43. (a)	44. (b)	45. (d)	46. (c)	47. (c)	48. (c)	49. (d)	50. (c)
51. (b)	52. (d)	53. (b)	54. (a)	55. (a)	56. (a)	57. (a)	58. (a)	59. (a)	60. (c)
61. (b)	62. (c)	63. (b)	64. (b)	65. (d)	66. (b)	67. (d)	68. (b)	69. (c)	70. (c)
71. (c)	72. (c)	73. (c)	74. (c)	75. (d)	76. (d)	77. (d)	78. (a)	79. (b)	80. (a)
81. (a)	82. (d)	83. (b)	84. (c)	85. (c)	86. (c)	87. (a)	88. (c)	89. (c)	90. (c)
91. (c)	92. (c)	93. (b)	94. (d)	95. (b)	96. (a)	97. (a)	98. (a)	99. (b)	100. (d)
101. (b)	102. (b)	103. (a)	104. (b)	105. (a)					

Explanations

1. (c) Nitric acid (HNO_3) is prepared on large scale by Ostwald's process.

(i) $4NH_3(g) + 5O_2 \xrightarrow[500K,9\ bar]{Pt/Rh\ gauge} 4NO(g) + 6H_2O(g)$
(air)

(ii) $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

(iii) $3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO(g)$
(nitric acid)

2. (a) The reactions takes place as:

$NH_2CONH_2 + H_2O \longrightarrow (NH_4)_2CO_3$
(A)

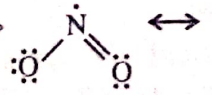
$\downarrow \Delta$

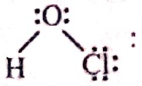
$NH_3(g) + CO_2(g) + H_2O(l)$
(B)

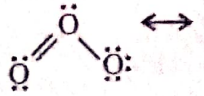
$NH_3(g) \xrightarrow{Cu^{2+}(aq)} [Cu(NH_3)_4]^{2+}$
(B) (C)
[Blue coloured solution]

3. (c) N_2O has linear, unsymmetrical structure. The structures are:

$N_2O \Rightarrow :N\equiv N-\ddot{O}: \leftrightarrow \ddot{N}=N=O$: Linear

$NO_2 \Rightarrow$  : Bent

$HOCl \Rightarrow$  : Bent

$O_3 \Rightarrow$  : Bent

4. (d)

A: Very pure introgen can be obtained from sodium azide or Barium azide. The reactions are:

$Ba(N_3)_2 \rightarrow Ba + 3N_2$

$2NaN_3 \rightarrow 2Na + 3N_2$

B: Ammonia is prepared by Haber's process on large scale:

The reaction involved is:

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

C: Sulphuric acid is obtained from contact process. The reactions involved are:-

$2SO_2(g) + O_2(g) \xrightarrow{V_2O_5} 2SO_3(g)$

$SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$

(oleum)

$H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$

D: Deacon's process is used for the preparation of chlorine. The reaction involved is

$4HCl + O_2 \xrightarrow{CuCl_2} 2Cl_2 + 2H_2O$

5. (a) The oxidation states of various N-comounds are:-

Let oxidation states of 'N' be 'x'

$HNO_3 : +1 + x + 3(-2) = 0 \Rightarrow x = +5$

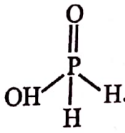
$NO : x - 2 = 0 \Rightarrow x = +2$

$N_2 : 2x = 0 \Rightarrow x = 0$

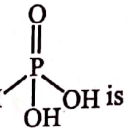
$NH_4Cl : x + 4 + 1(-1) = 0 \Rightarrow x = -3$

Hence, the correct decreasing order is HNO_3, NO, N_2, NH_4Cl.

6. (b) The structure of Phosphinic acid (Hypophosphorous acid) is



H. It is a monoprotic acid as it contains only one ionisable H-atom.

While phosphonic acid is H_3PO_3. Its structure is  OH is a diprotic acid as it contains two ionsiable H-atoms.

Ionisable H-atom is one which is attached to more electronegative atom.

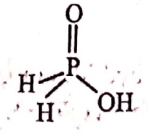
7. (b) $Cu + HNO_3\,(conc.) \rightarrow Cu(NO_3)_2 + 2NO_2 + H_2O$

(Brown gas)

Hence, $Cu(NO_3)_2$ and NO_2 is being produced.

8. (b) A reducing agent is one that itself undergoes oxidation but causes reduction of others.

In H_3PO_2, presence of 2P - H bonds and one O - H bond makes H_3PO_2 a reducing agent as it can easity lose H-atoms, thus can undergo itself oxidation.



9. (b) NO_2 is not used as a food preservative but SO_2 can be.

10. (d) Heating of ammonium dichromate yields nitrogen. Its a laboratory preparation for nitrogen.

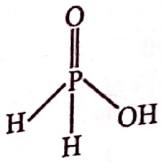
$(NH_4)_2Cr_2O_7 \xrightarrow{\Delta} N_2 + Cr_2O_3 + H_2O$

$2KClO_3 \xrightarrow{\Delta} 2KCl + 3O_2$

$Zn(ClO_3)_2 \xrightarrow{\Delta} ZnCl_2 + 3O_2$

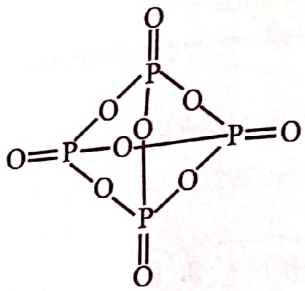
$K_2Cr_2O_7 \xrightarrow{\Delta} 2K_2CrO_4 + Cr_2O_2 + \frac{3}{2}O_2$

11. (c)



It is monoprotic acid as it contains only one ionisable H-atom. Ionisable H-atom is one which is attached to more electronegative atom.

12. (a)



It can be clearly seen from the structure that it has 6 bridging O-atoms.

13. (d) The oxidation state can be calculated as:

$H_4P_2O_5$

$+4 + 2x + 5(-2) = 0$

$2x - 6 = 0$

$x = +3$

$H_4P_2O_6$

$+4 + 2x + 6(-2) = 0$

$2x - 8 = 0$

$x = +4$

$H_4P_2O_7$

$+4 + 2x + 7(-2) = 0$

$2x - 10 = 0$

$2x = 10$

$x = +5$

14. (c) Bi_2O_3 forms the most basic oxide, as metals forms basic oxides. As we go down the group metallic character increases.

15. (a) Acidic nature decrease down the group so N_2O_5 is most acidic.

16. (b) White phosphorous has low ignition temperature so it is most reactive.

17. (c) Due to greater electronegativity of nitrogen, dipole moment for NH_3 is greater.

18. (c) The formula of hypophosphorous acid is H_3PO_2 as shown in c. It is monobasic acid.

19. **(a)** All the hydrides of group V elements have one lone pair of electrons on their central atom. Therefore, they can act as Lewis bases. The basic character of these hydrides decreases down the group.

20. **(a)** The acidic character of the oxides decreases with the decrease in the oxidation state and also decreases down the group. Thus, due to As in As_4O_6 being in lowest oxidation state of +3 and also present below in the group after P, makes it least acidic.

21. **(a)** NO_2 is paramagnetic due to the presence of unpaired electrons.

22. **(a)** Except nitrogen and bismuth, all elements of fifth group form pentahalides especially pentafluorides. Since, nitrogen cannot form pentahalides therefore, it cannot expand its octet due to non-availability of *d*-orbitals.

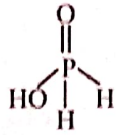
23. **(a)** P_2O_5 absorbs moisture much readily than anhydrous $CaCl_2$.

24. **(a)** Nitrogen molecule is diatomic containing a triple bond between two N atoms, $\overset{\cdot\cdot}{N} \equiv \overset{\cdot\cdot}{N}$. Therefore, nitrogen molecule is formed by sharing six electrons.

25. **(b)** $\underset{\text{Cane sugar}}{C_{12}H_{22}O_{11}} + \underset{\text{From } HNO_3}{18[O]} \rightarrow \underset{\text{Oxalic acid}}{6(COOH)_2} + 5H_2O$

26. **(d)** N_2 molecule contains triple bond between N atoms and the energy required to break this bond is quite high. Very high dissociation energy (946 kJ mol^{-1}) due to which it is relatively inactive.

27. **(c)** H_3PO_2 is named as hypophosphorous acid and it contains only one P–OH group. Since it contains only one ionisable H-atom, therefore, it is monobasic.

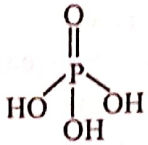


28. **(d)** Aqueous solution of ammonia is obtained by passing NH_3 in water and the reaction takes place as:

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

29. **(d)** $P_2O_5 + 3H_2O \xrightarrow{\Delta} 2H_3PO_4$

30. **(b)** Orthophosphoric acid, H_3PO_4 contains three P–OH groups, since hydrogen atom attached to more electronegative O-atom are ionisable, therefore, it contains three ionisable H-atoms. Hence, it is tribasic.



31. **(b)** $PCl_3 + 3H_2O \rightarrow H_3PO_3 + 3HCl$

32. **(a)** $PH_4I + NaOH \rightarrow NaI + PH_3 + H_2O$

33. **(d)** $NH_4Cl + NaNO_2 \xrightarrow{\text{Heat}} NH_4NO_2 + NaCl$
$NH_4NO_2 \xrightarrow{\Delta} N_2 + 2H_2O$

34. **(b)** Nitrogen belongs to p-block elements. It's electronic configuration is $1s^2\ 2s^2\ 2p^3$. Hence, it can be clearly seen that d-orbitals are not available.

35. **(a)** All the elements of group 15 form trihalides and pentahalides of the type MX_3 and MX_5 except nitrogen which forms only trihalides. Nitrogen does not forms pentahalides due to the absence of *d*-orbitals in its valence shell.

36. **(a)** Red phosphorus is insoluble in CS_2 and only white P is soluble in CS_2.

37. **(d)** On heating, it gives pyrophosphoric acid at 525 K and metaphosphoric acid at 875 K.

$$2H_3PO_4 \xrightarrow[-H_2O]{525K} \underset{\text{pyrophosphoric acid}}{H_4P_2O_7} \xrightarrow[-H_2O]{875K} \underset{\text{Metaphosphoric acid}}{2HPO_3}$$

38. **(b)** Due to the absence of H-bonding, PH_3 has the lowest boiling point. The boiling point of the V group hydrides is: $BiH_3 > SbH_3 > NH_3 > AsH_3 > PH_3$

39. **(c)** When 2-molecules of nitric acid undergoes heating, it lose a water molecule to form an anhydride.

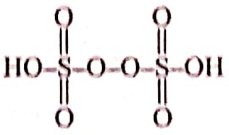
$$\begin{bmatrix} HO \cdot NO_2 \\ HO \cdot NO_2 \end{bmatrix} \xrightarrow{\Delta} N_2O_5 + H_2O$$

Thus, N_2O_5 is nitric acid anhydride.

40. **(d)** BF_3 behaves as Lewis acid due to incomplete octet in valence shell of Boron. Hence it can accept a lone pair of electrons.

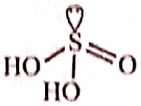
41. **(c)**

$H_2S_2O_8$, peroxodisulphuric acid



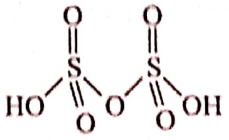
(Two S-OH, Four S=O, One S-O-O-S)

H_2SO_3, sulphurous acid



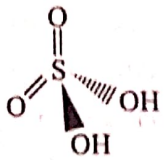
(Two S-OH, One S=O bond)

$H_2S_2O_7$, pyrosulphuric acid



(Two S-OH, Four S = O, One S-O-S bond)

H_2SO_4, sulphuric acid



(Two S-OH, Two S=O)

42. **(c)** The boiling point of hydrides is affected by two major fators:

(1) Hydrogen bonding

(2) Molecular mass

The boiling point of hydrides of group-16 elements follows the order: $H_2O > H_2Te > H_2Se > H_2S$.

H_2O is having exceptionally high boiling point because of the presence of hydrogen bonding. In the rest of the hydrides, the boiling poing increases with an increase in molecular mass.

43. (a) The acidic character is explained on the basis of a tendency of molecule to lose H^+ ion which is related to bond dissociation enthalpy. On moving down the group, bond dissociation enthalpy of hydrides of group 16 elements decreases due to increase in the size of the atom. Hence, the acidic character increases from H_2O To H_2Te.

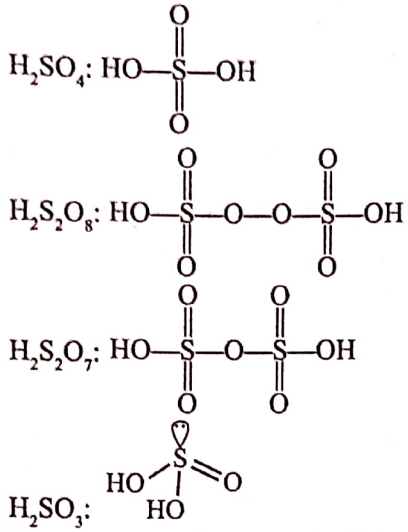
Also, as acidity increases, the pK_a value decreases.

That is, Stronger is the acid, lower is the value of pK_a.

Therefore, the correct order of pK_a value will be

$H_2O > H_2S > H_2Se > H_2Te$

44. (b) The structures of the various oxoacid of sulphur are:-



Hence, we can clearly see that $H_2S_2O_8$ has –O–O– linkage

45. (d) Concentrated sulphuric acid is a strong dehydrating agent and it readily dehydrate carbohydrates into carbon

$$2C_{12}H_{22}O_{11} + \text{conc. } H_2SO_4(\text{conc}) \rightarrow 12C + 11H_2O$$

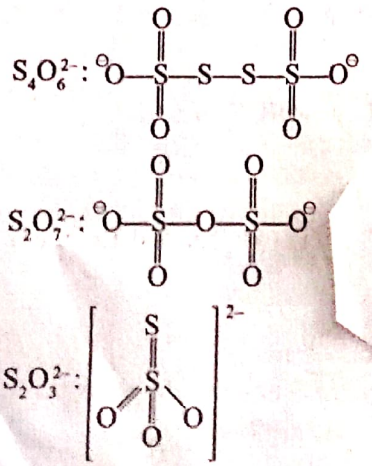
The reaction of concentrated sulphuric acid with carbohydrates ($C_{12}H_{22}O_{11}$) is an example of dehydration.

46. (c) Thermal stability order for H_2E decrease down the group because H – E bond energy decreases on going down the group due to increase in the size of the atom 'E'.

∴ Order of stability would be:-

$H_2Po < H_2Te < H_2Se < H_2S < H_2O$

47. (c) The structure for the various species are:



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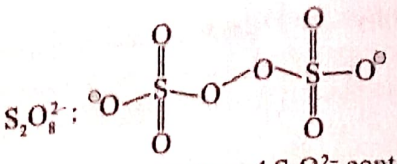
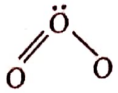


Hence, only, $S_4O_6^{2-}$ and $S_2O_3^{2-}$ contains S–S bond

48. (c)

(a) The structure of O_3 molecule is bent due to the p of lone pair.



(b) The no. of electrons in ONF = 8 + 7 +9 = 24

The no. of electrons in O_2N^- = 8 + 8 + 7 + 1 = 24

Since, both have same number of e^{-1}s, therefo isoelectronic in nature.

(c) OF_2 is of fluoride of oxygen because fluorine ha electronegative than oxygen.

(d) The anhydride of an acid is the compound le removing a water molecular from it.

$$\underset{\text{Perchloric acid}}{2HClO_4} \xrightarrow{\Delta} Cl_2O_7 + H_2O$$

Hence, Cl_2O_7 is an anhydride of perchloric acid, HCl(

49. (d) The strength of acid is strictly proportional to the of compound release H^+ in easily. With increase in the size, the strength of the bond between hydrogen a central atom decreases, as a result, H^+ can be released since the bond M–H gets weakened.

Hence, the correct acidic strength order is

$H_2S < H_2Se < H_2Te$

50. (c) The acidic character is explained on the basis of dissociation enthalpy. On moving down the group, dissociation enthalpy of hydrides of group 16 ele decreases due to increase in the size of the atom.

The acidic character increases from H_2O To H_2Te.

Also, as acidity increases, the pK_a value decreases.

That is, Stronger is the acid, lower is the value of pK_a.

Therefore, the correct order of pK_a value will be

$H_2O > H_2S > H_2Se > H_2Te$

51. (b) $Fe_2(SO_4)_3 \xrightarrow{\Delta} Fe_2O_3 + 3SO_3$

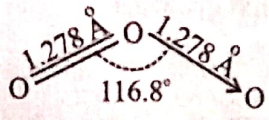
52. (d) Sulphuric Acid → Contact's process

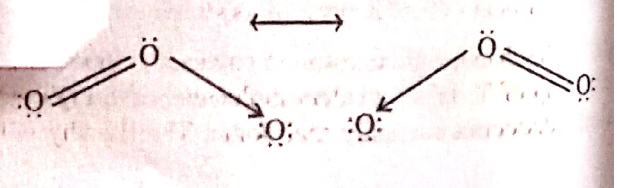
Ammonia → Haber's process

Sodium Hydroxide→ Leblanc process

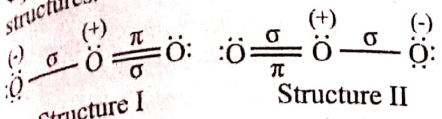
Steel → Bessemer's process

53. (b) The angular shape of ozone molecule (O_3) is:





O_3 molecules can be represented by the following two lewis structures.



Structure I Structure II

54. (a) Acidic character increases in the order :

$Na_2O < Na_2S < Na_2Se < Na_2Te$

Basic character of conjugate bases will be in the order: $O^{2-} > S^{2-} > Se^{2-} > Te^{2-}$. More the basic character, more the pH

$\therefore pH_1 > pH_2 > pH_3 > pH_4$

55. (a) $S_2O_4^{2-} < SO_3^{2-} < S_2O_6^{2-}$

Oxidation state of sulphur in each case are

$S_2O_4^{2-} = 2x + (-8) = -2 \Rightarrow x = +3$

$SO_3^{2-} = x + (-6) = -2 \Rightarrow x = +4$

$S_2O_6^{2-} = 2x + (-12) = -2 \Rightarrow x = +5$

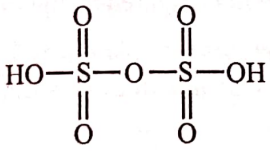
56. (a) O–O bond has lower energy than S-S bond due to more inter electronic repulsions between two small oxygen atoms.

57. (a) $2Na_2S_2O_3 + I_2 \rightarrow Na_2S_4O_6 + 2\,NaI$.
(Sodium tetrathionate)

58. (a) Ozone layer is very beneficial to us, because it stops harmful ultraviolet radiations to reach the earth.

59. (a) Alkaline solution of pyrogallol absorbs oxygen quickly.

60. (c) Pyrosulphuric acid or oleum (+6) is $H_2S_2O_7$ which is obtained by dissolving SO_3 and is called fuming sulphuric acid.



61. (b) Alkaline pyrogallol absorbs O_2 and oil of cinnamon absorbs O_3.

62. (c) Oxygen gas is prepared by fractional distillation of air. During this process, dinitrogen with less boiling point (78K) distills as vapours while dioxygen with higher boiling point 90 K) remains in the liquid state and can be separated.

63. (b) $X_{2(g)} \xrightarrow[\text{endothermic}]{\Delta H_{diss}} 2X_{(g)} \xrightarrow[\text{electron gain enthalpy (exothermic)}]{e^-} X^-_{(g)} \xrightarrow[\text{hydration energy (exothermic)}]{H_2O,\ \Delta H} X^-_{aq}$

More energy is released on adding these values for fluorine due to their low bond dissociation enthalpy and high hydration enthalpy.

64. (b) ICl is an interhalogen compound made of I and Cl. Iodine is having low value of electronegativity than Cl. Thus, the ICl has a partical ionic character in its structure.

On the other hand, Iodine is a pure covalent compound as it is made up of 'I' only. Covalent molecules have high value of bond dissociation energy than ionic. That is why ICl is having weaker bond and low bond dissociation energy and hence reactive in nature.

65. **(d)** Acid strength depends on the ability of a substance to lose H^+ ion. More easily, it loses H^+ ion, more will be its acidic strength.

Since in the case of H – F, the bond dissociation enthalpy is more, so it is difficult to lose H^+ ion, hence least acidic.

Also, as we more down the group 17, the size of the halogen increases from F to I, so dissociation enthalpy decreases in the same order. Hence, we can say more dissociation enthalpy, less acidic strength.

H – X Bond dissociation enthalpy order: H – F > H – Cl > H – Br > H – I

Hence, correct order strength is HF << HCl < HBr << HI.

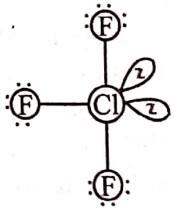
66. **(b)** For a reaction to come under hydrolysis type, there should be no change in oxidation number. But in the reaction between F_2 and H_2O, fluorine oxidises water into oxygen as shown below.

$$\overset{-1}{F_2} + \overset{+1\ -2}{H_2O} \rightarrow \overset{+1\ -1}{2HF} + \frac{1}{2}\overset{0}{O_2}$$

Since, oxidation number of O changes from –2 to 0, hence, it is not a hydrolysis reaction.

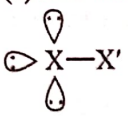
67. **(d)** All halogens show +ve and–ve oxidation state while F show –ve oxidation state due to high electronegativity and small size.

68. **(b)** According to VSEPR theory, the structure of ClF_3 is



Hence, the number of lone pair of electrons on central Cl is 2.

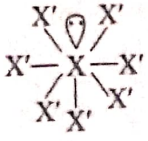
69. **(c)** XX' has Linear shape as only two atoms are present.



XX'_3 has T shape as 3 bps and 2lps of electrons are present.

XX'_3 has square pyramidal as 5 bps and 1lp of electron is present.

XX'_7 has Pentagonal bipyramidal as 7bps and 1lp of e^-s are present.



70. (c) Bond dissociation energy of halogen family decreases down the group as the size of the atom increases. The bond dissociation energy of fluorine is, however, lower than that of chlorine and bromine because of inter-electronic repulsions present in the small atom of fluorine

Hence bond energy decreases in the order:

$Cl_2 > Br_2 > F_2 > I_2$

71. (c) As the oxidation number of central atom increases, acidic nature increases.

The oxidation state of Cl can be calculated as:

$HClO_4$: $+1 + x + 4(-2) = 0$

$\Rightarrow x = +7$

$HClO_3$: $+1 + x + 3(-2) = 0$

$\Rightarrow x = +5$

$HClO_2$: $+1 + x + 2(-2) = 0$

$\Rightarrow x = +3$

HClO: $+1 + x - 2 = 0$

$\Rightarrow x = +1$

Hence the correct order of acidity among oxo acids of Cl is $HClO_4 > HClO_3 > HClO_2 > HClO$.

72. (c) HF forms strong intermolecular H–bonding due to high electronegativity of F. Hence, the boiling point of HF is abnormally high. Boiling points of other hydrogen halides gradually increase from HCl to HI due to increase in size of halogen atoms from Cl to I which further increase the magnitude of vander waals forces.

73. (c) $HClO_4$ is the strongest acid, as it has greater number of 'O' atoms, so, more e^-s will be pulled away from O–H bond and more this bond will be weakened. And more easily H^+ ion will be lost. But in between H_2SO_4 and $HClO_4$, $HClO_4$ is strong because perchlorate ion formed by removal of hydrogen atom is more stabilised than sulphate ion as negative charge is more dispersed in perchlorate ion

74. (c) $Cl_2 + NaOH$ (hot & concentrated) $\rightarrow NaCl + NaClO_3$

In NaCl oxidation state of Cl = –1

In ClO_3^- oxidation state of Cl = +5

Oxidation state of Cl changes from zero to –1 and zero to +5.

75. (d) Order of bond dissociation enthalpy for halogen gases is:

$Cl_2 > F_2 > Br_2 > I_2$

76. (d) $\overset{+1}{HOCl} < \overset{+3}{HClO_2} < \overset{+5}{HClO_3} < \overset{+7}{HClO_4}$

As the number of oxygen atom increases, an increasing amount of electron density shifts from Cl atom to more electronegative O atom. Hence as the oxidation number of Cl atom increases, due to which the amount of actual positive charge on Cl atom increases which in turn attracts the electron density from O – H bond, hence the O – H bond is weakened and proton is easily released and acidity increases.

77. (d) Bond dissociation enthalpy for halogen is:

$Cl_2 > F_2 > Br_2 > I_2$

78. (a) $HClO_4 > HClO_3 > HClO_2 > HClO$

As the number of oxygen atom increases, an increasing amount of electron density shifts from Cl atom to more electronegative O atom. Hence as the oxidation number of Cl atom increases, due to which the amount of actual positive charge on Cl atom increases which in turn attracts the electron density from O – H bond, hence the O – H bond is weakened and proton is easily released and acidity increases.

79. (b) Bond energy of chlorine is greater than fluorine, because in F_2 due to $e^- - e^-$ repulsion between two F-atoms, bond gets broken down easily, hence has low bond dissociation energy.

80. (a) Generally, Electron affinity of elements decreases down the group because of increasing size of atom, so the order should be: I < Br < Cl < F.

But in group 17, fluorine has lower electron effinity as compared to chlorine due to very small size of fluorine atom, as a result of which, there are more $e^- - e^-$ repulsions in F and than Cl.

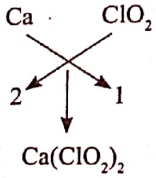
Hence the correct order is

I < Br < F < Cl.

81. (a) Bromine is soluble in CCl_4 and CS_2. Animal charcoal also absorb on bromine water. Piece of marble has no action with Br_2 so after adding ($CaCO_3$) marble piece to the flask, there will no decrement in the intensity of brown colour

82. (d) In general, the electron affinity decreases from top to bottom in a group. But in group 17, fluorine has lower electron affinity as compared to chlorine due to very small size of fluorine atom, as a result of which there are more $e^- - e^-$ repulsions in F than Cl. Hence, the tendency to accept e^- in F decreases as compared to Cl.

83. (b) Since the valency of calcium is 2 and a chlorite ion is ClO_2^-, therefore calcium chlorite is $Ca(ClO_2)_2$.



$Ca(ClO_2)_2$

84. (c) Since chlorine is more electronegative than bromine therefore it will displace bromine from an aqueous solution containing bromide ions.

$Cl_2 + 2Br^- \rightarrow 2Cl^- + Br_2$

85. (c) Outer electronic configuration of Cl

$= 3s^2 3p_x^2 p_y^2 p_z^1, :\ddot{\underset{\cdot\cdot}{Cl}}\cdot$

Outer electronic configuration of $Cl^- = 3s^2 3p_x^2 p_y^2 p_z^2, :\ddot{\underset{\cdot\cdot}{Cl}}:$ i.e. 4 lone pair of electrons.

86. (c) A stronger oxidising agent (Cl_2) displaces a weaker oxidising agent (Br_2) from its salt solution.

$2KBr + Cl_2 \rightarrow 2KCl + Br_2$

87. (a) Caustic soda is manufactured by the electrolysis of NaCl solution where Cl_2 is evolved at the anode and H_2 at the cathode.

At anode : $Cl^- \rightarrow Cl + e^-$, $Cl + Cl \rightarrow Cl_2 \uparrow$

At cathode : $Na^+ + e^- \rightarrow Na$

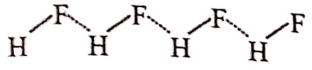
(c) N, O and F are highly electronegative non metals and will have the strongest tendency to form anions by gaining electrons from metal atoms.

(c) Polarity of the bond depends upon the electronegativity difference of the two atoms forming the bond. Greater the electronegativity difference, more is the polarity of the bond.

N – Cl	O – F	N – F	N – N
3.0–3.0	3.5–4.0	3.0–4.0	3.0–3.0

(c) As halogens have seven electrons ($ns^2 np^5$) in the valence shell, they have a strong tendency to acquire the nearest inert gas configuration by gaining an electron from the metallic atom and form halide ions easily.

(c) Fluorine because of its smaller size and highest electronegativity shows strongest hydrogen bonding.



(c) $Ca(OH)_2 + Cl_2 \rightarrow CaOCl_2 + H_2O$

(b) Bromide in the mother liquor (containing $MgBr_2$) is oxidised to Br_2 by passing Cl_2 which is a stronger oxidizing agent.

$2Br^- + Cl_2 \rightarrow Br_2 + 2Cl^-$

(d) Bleaching action of chlorine is due to liberation of nascent oxygen by oxidation in presence of moisture. It is permanent.

$H_2O + Cl_2 \rightarrow 2HCl + [O]$

Colouring matter + [O] $\rightarrow$ colourless matter

(b) Chlorine does not react directly with oxygen.

(a) $CaOCl_2 + 2HCl \rightarrow CaCl_2 + H_2O + Cl_2$.

The liberated Cl_2 gives the disinfectant nature to bleaching powder.

$Cl_2 + H_2O \rightarrow HCl + HOCl$ (Kill germs)

(a) Noble gases have a fully filled electron configuration because of that they have weak London forces in between them. Therefore, Noble gases have low melting and boiling points.

(a) According to VSEPR theory, Hybridisation state = no. of l.p. on central atom + no. of b.p made by central atom.

In XeF_2, Xe has made two bonds with F–atom, therefore, has 3 *l*–p's.

Hybridisation state = 3 + 2 = 5

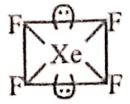
Hence, corresponds to linear shape with sp^3d hybridisation.

XeF_2: Linear

In XeF_4, Xe has made 4 bonds with F–atom, therefore has 2 *l*–p's.

Hybridisation state = 2 + 4 = 6

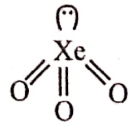
Hence, corresponds to square planar shape with sp^3d^2 hybridisation.

XeF_4:  Sqaure planar

In XeO_3, Xe has made 3 bonds pairs with F–atom, therefore has one *l*.p.

Hybridisation state = 1 + 3 = 4

Hence, corresponds to pyramidal shape with sp^3 hybridisation.

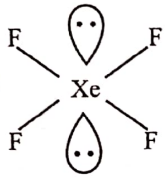
XeO_3:  Pyramidal

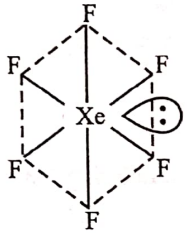
In $XeOF_4$, Xe has made 5 bonds pairs with F–atom, therefore, has one lp. Hybridisation state = 1 + 5 = 6

Hence, corresponds to pyramidal shape with sp^3d^2 hybridisation.

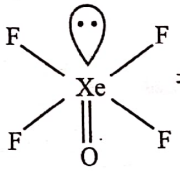
$XeOF_4$: Square pyramidal

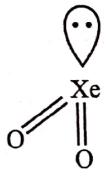
99. (b)

A. XeF_4:  ⇒ Square Planar

B. XeF_6:  ⇒ Distorted octahedral

In XeF_6, Xe has made six bonds with F – atom, therefore has one lone pair, as a result of which, it has a distorted octainedral structure as found experimentally in the gas phase.

C. $XeOF_4$:  ⇒ Square pyramidal

D. XeO_3:  ⇒ Pyramidal

100. (d) **Isostructural species** are those which have same shape and hybridisation. **Isoelectronic species** are those which have same number of electrons.

In IBr_2^-, the total number of electrons present are 22.

It can be understood in the following way:-

No. of electrons in the valence shell of I–atom = 7

No. of electrons in the valence shell of two Br–atom = 7 + 7 = 14

Since, it acquires one negative charge, therefore, it will have one extra electron present in it. Thus, total number of electrons present in it are 7 + 14 + 1 = 22.

Now, the shape of IBr_2^- can be explained on the basis of VSEPR theory. According to VSEPR Theory,

Hybridisation state of I = No. of sigma bonds made by I–atom + No. of l.p. on I–atom

= 2 + 3 = 5

Hence, it has linear shape with sp^3d hybridisation.

In XeF_2, the total number of electrons present are 22.

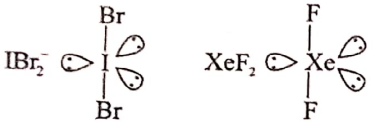
No. of electrons in the valence shell of Xe–atom = 8

No. of electrons in the valence shell of 2F–atom = 7 + 7 = 14

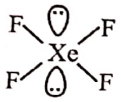
Total electrons = 8 + 14 = 22

According to VSEPR theory, XeF_2 has linear shape.

Since XeF_2 and IBr_2^- both have same no. of electons and same shape, therefore both are isoelectronic and isostructural.



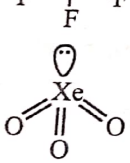
101. (b)

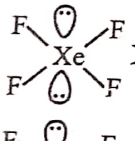


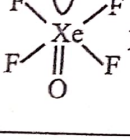
XeF_4 is a AB_4L_2 type molecule with 4 – bond pair & 2 lone pair. Therefore as per VSEPR theory, it has Octahedral geometry & shape is square planar with hybridisation sp^3d^2.

102. (b)

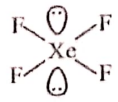
XeF_6 – Distorted octahedral geometry

 XeO_3 – Pyramidal

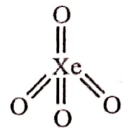
 XeF_4 – Square planar

 $XeOF_4$ – Square pyramidal

103. (a) Isostructural species are those which have same shape and hydridisation.



$XeF_4 \rightarrow$ Square planar



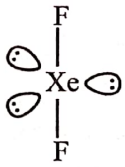
$XeO_4 \rightarrow$ Tetrahedral structure non-identical geometry.

104. (b) XeF_2 is isostructural with ICl_2^-. Isostructural species are those which have same shape and hybridisation.

In XeF_2, Xe has made two bonds with F–atom, and hence has 3 l.p's

Hybridisation state = 3 + 2 = 5

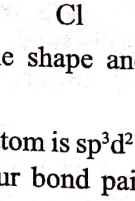
Therefore, according to VSEPR theory, it has linear shape due to the presence of three lp's and has sp^3d hybridisation.



In ICl_2^-, I has made two bonds with Cl – atom and hence has 3 lp's

Hybridisation state = 3 + 2 = 5

Therefore, according to VSEPR theory, it has linear shape due to the presence of three lp's and has sp^3d hybridisation.



Since both have same shape and hybridisation, therefore, they are isostructural.

105. (a) In XeF_4, the 'Xe' atom is sp^3d^2 hybridised, which contains two lone pair and four bond pair. Therefore, the shape of XeF_4 molecule is square planar.

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CHAPTER 5

The d-and f-Block Elements

Transition Elements (d-Block)

1. The stability of Cu^{2+} is more than Cu^{+} salts in aqueous solutions due to: [MR*] *(2023)*

a. second ionisation enthalpy
b. first ionisation enthalpy
c. enthalpy of atomisation
d. hydration energy

2. Which of the following is **correctly** matched ? [MR*] *(2023-Manipur)*

a. Basic oxides ⇒ In_2O_3, K_2O, SnO_2
b. Neutral oxides ⇒ CO, NO_2, N_2O
c. Acidic oxides ⇒ Mn_2O_7, SO_2, TeO_3
d. Amphoteric oxides ⇒ BeO, Ga_2O_3, GeO

3. Given below are two statements : *(2022 Re)*

Statement I: Cr^{2+} is oxidising and Mn^{3+} is reducing in nature.

Statement II: Sc^{3+} compounds are repelled by the applied magnetic field.

In the light of the above statements, choose the **most appropriate** answer from the options given below:

a. Statement I is incorrect but Statement II is correct
b. Both Statement I and Statement II are correct
c. Both Statement I and Statement II are incorrect
d. Statement I is correct but Statement II is incorrect

4. Zr (Z = 40) and Hf (Z = 72) have similar atomic and ionic radii because of: *(2021)*

a. Diagonal relationship
b. Lanthanoid contraction
c. Having similar chemical properties
d. Belonging to same group

5. The calculated spin only magnetic moment of Cr^{2+} ion is *(2020)*

a. 4.90 BM b. 5.92 BM
c. 2.84 BM d. 3.87 BM

6. Match the following aspects with the respective metal. *(2020-Covid)*

	Aspects		Metal
A.	The metal which reveals a maximum number of oxidation states	i.	Scandium
B.	The metal although placed in 3d block is considered not as a transition element	ii.	Copper
C.	The metal which does not exhibit variable oxidation states	iii.	Manganese
D.	The metal which in +1 oxidation state in aqueous solution undergoes disproportionation	iv.	Zinc

Select the correct option:

a. A-iii B-iv C-i D-ii
b. A-iii B-i C-iv D-ii
c. A-ii B-iv C-i D-iii
d. A-i B-iv C-ii D-iii

7. Match the metal ions given in Column-I with the spin magnetic moments of the ions given in Column-II and assign the correct code: [MR*] *(2018)*

	Column-I		Column-II
A.	Co^{3+}	i.	$\sqrt{8}$ B.M
B.	Cr^{3+}	ii.	$\sqrt{35}$ B.M
C.	Fe^{3+}	iii.	$\sqrt{3}$ B.M
D.	Ni^{2+}	iv.	$\sqrt{24}$ B.M
		v.	$\sqrt{15}$ B.M

a. A-iv B-v C-ii D-i
b. A-i B-ii C-iii D-iv
c. A-iii B-v C-i D-ii
d. A-iv B-i C-ii D-iii

8. $HgCl_2$ and I_2 both when dissolved in water containing I^- ions the pair of species formed is: *(2017-Delhi)*
   a. Hg_2I_2, I^- b. HgI_2, I_3^-
   c. HgI_2, I^- d. HgI_4^{2-}, I_3^-

9. Which of the following processes does not involve oxidation of iron? *(2015)*
   a. Decolourisation of blue $CuSO_4$ solution by iron
   b. Formation of $Fe(CO)_5$ from Fe
   c. Liberation of H_2 from steam by iron at high temperature
   d. Rusting of iron sheets

10. Magnetic moment 2.84 B.M. is given by: (Atomic numbers, Ni = 28, Ti = 22, Cr = 24, Co = 27) *(2015)*
   a. Ti^{3+} b. Cr^{2+}
   c. Co^{2+} d. Ni^{2+}

11. Because of lanthanoid contraction, which of the following pairs of elements have nearly same atomic radii? (Numbers in the parenthesis are atomic numbers) *(2015)*
   a. Zr (40) and Nb (41) b. Zr (40) and Hf (72)
   c. Zr (40) and Ta (73) d. Ti (22) and Zr (40)

12. Magnetic moment 2.83 BM is given by which of the following ions? *(2014)*
   (Atomic Number Ti = 22, Cr = 24, Mn = 25, Ni = 28)
   a. Ni^{2+} b. Cr^{3+}
   c. Mn^{2+} d. Ti^{3+}

13. Which of the following statements about the interstitial compounds is incorrect? *(2013)*
   a. They retain metallic conductivity
   b. They are chemically reactive
   c. They are much harder than the pure metal
   d. They have higher melting points than the pure metal

14. Which one of the following does not correctly represent the correct order of the property indicated against it? **[MR*]** *(2012 Mains)*
   a. Ti < V < Mn < Cr : increasing 2nd ionization enthalpy
   b. Ti < V < Cr < Mn : increasing number of oxidation states
   c. $Ti^{3+} < V^{3+} < Cr^{3+} < Mn^{3+}$: increasing magnetic moment
   d. Ti < V < Cr < Mn : increasing melting points

15. The catalytic activity of transition metals and their compounds is ascribed mainly to: *(2012 Mains)*
   a. Their chemical reactivity
   b. Their magnetic behaviour
   c. Their unfilled d-orbitals
   d. Their ability to adopt variable oxidation states

16. Four successive members of the first series of the transition metals are listed below. For which one of them the standard potential $E^0_{M^{2+}/M}$ value has a positive sign? *(2012 Mains)*
   a. Fe (Z = 26) b. Co (Z = 27)
   c. Ni (Z = 28) d. Cu (Z = 29)

17. Identify the alloy contaning a non-metal as a constituent in it. *(2012 Pre)*
   a. Invar b. Steel
   c. Bell metal d. Bronze

18. From the four successive transition elements (Cr, Mn, Fe and Co), the stability of + 2 oxidation state will be there in which of the following order? *(2011 Pre)*
   (Atomic Number Cr = 24, Mn = 25, Fe = 26, Co = 27)
   a. Cr > Mn > Co > Fe b. Mn > Fe > Cr > Co
   c. Fe > Mn > Co > Cr d. Co > Mn > Fe > Cr

19. Which of the following ions will exhibit colour in aqueous solutions? **[MR*]** *(2010 Pre)*
   a. Sc^{3+} (Z = 21) b. La^{3+} (Z = 57)
   c. Ti^{3+} (Z = 22) d. Lu^{3+} (Z = 71)

20. Which one of the following ions has electronic configuration [Ar]$3d^6$? *(2010 Pre)*
   a. Co^{3+} b. Ni^{3+}
   c. Mn^{3+} d. Fe^{3+}

21. Which of the following pairs has the same size? *(2010 Pre)*
   a. Zn^{2+}, Hf^{4+} b. Fe^{2+}, Ni^{2+}
   c. Zr^{4+}, Ti^{4+} d. Zr^{4+}, Hf^{4+}

22. Which one of the elements with the following outer orbital configurations may exhibit the largest number of oxidation states? *(2009)*
   a. $3d^54s^1$ b. $3d^54s^2$
   c. $3d^24s^2$ d. $3d^34s^2$

23. The correct order of decreasing second ionisation enthalpy of Ti (22), V (23), Cr (24) and Mn (25) is: *(2008)*
   a. Ti > V > Cr > Mn b. Cr > Mn > V > Ti
   c. V > Mn > Cr > Ti d. Mn > Cr > Ti > V

24. Which one of the following ions is the most stable in aqueous solution? *(2007)*
   a. V^{3+} b. Ti^{3+}
   c. Mn^{3+} d. Cr^{3+}
   (Atomic Number Ti = 22, V = 23, Cr = 24, Mn = 25)

25. In which of the following pairs are both the ions coloured in aqueous solution?
   (Atomic number : Sc = 21, Ti = 22, Ni = 28, Cu = 29, Co = 27) *(2006)*
   a. Ni^{2+}, Ti^{3+} b. Sc^{3+}, Ti^{3+}
   c. Sc^{3+}, Co^{2+} d. Ni^{2+}, Cu^{+}

26. Four successive members of the first row transition elements are listed below with their atomic numbers. Which one of them is expected to have the highest third ionization enthalpy? **[MR*]** *(2005)*
   a. Vanadium (Z = 23) b. Chromium (Z = 24)
   c. Iron (Z = 26) d. Manganese (Z = 25)

27. The aqueous solution containing which one of the following ions will be colourless? (Atomic number: Sc = 21, Fe = 26, Ti = 22, Mn = 25) *(2005)*
   a. Sc^{3+} b. Fe^{2+}
   c. Ti^{3+} d. Mn^{2+}

28. Among the following series of transition metal ions, the one where all metal ions have $3d^2$ electronic configuration is: [MR*] *(2004)*

(Atomic numbers of Ti = 22; V = 23; Cr = 24; Mn = 25)

a. Ti^{+}, V^{4+}, Cr^{6+}, Mn^{7+} b. Ti^{4+}, V^{3+}, Cr^{2+}, Mn^{3+}

c. Ti^{2+}, V^{3+}, Cr^{4+}, Mn^{5+} d. Ti^{3+}, V^{2+}, Cr^{3+}, Mn^{4+}

29. Among K, Ca, Fe and Zn, the element which can form more than one binary compound with chlorine is *(2004)*

a. Zn b. K

c. Ca d. Fe

30. Which one of the following characteristics of the transition metals is associated with their catalytic activity? *(2003)*

a. High enthalpy of atomization

b. Paramagnetic behaviour

c. Colour of hydrated ions

d. Variable oxidation states

31. The basic character of the transition metal monoxides follows the order: [MR*] *(2003)*

(Atomic numbers Ti = 22, V = 23, Cr = 24, Fe = 26)

a. VO > CrO > TiO > FeO

b. CrO > VO > FeO > TiO

c. TiO > FeO > VO > CrO

d. TiO > VO > CrO > FeO

32. An atom has electronic configuration $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3\ 4s^2$, you will place it in which group: *(2002)*

a. Fifth b. Fifteenth

c. Second d. Third

33. Which of the following shows maximum number of oxidation states? *(2002)*

a. Cr b. Fe

c. Mn d. V

34. The most convenient method to protect the bottom of ship made of iron is: [OS] *(2001)*

a. Coating it with Red lead oxide

b. White tin plating

c. Connecting it with Mg block

d. Connecting it with Pb block

35. Which ion is colourless? *(2000)*

a. Cr^{+4} b. Sc^{+3}

c. Ti^{+3} d. V^{+3}

36. Which of the following element exhibit maximum oxidation state? *(2000)*

a. Cr b. Mn

c. Fe d. V

37. Which one of the following ionic species will impart colour to an aqueous solution? *(1998)*

a. Ti^{4+} b. Cu^{+}

c. Zn^{2+} d. Cr^{3+}

38. Which of the following does not represent the correct order of property stated against is? *(1997)*

a. $Ni^{2+} < Co^{2+} < Fe^{2+} < Mn^{2+}$; ionic size

b. $Co^{3+} < Ce^{3+} < Cr^{3+} < Sc^{3+}$; stability in aq. med.

c. Sc < Ti < Cr < Mn; no. of oxidation states

d. $V^{2+} < Cr^{2+} < Mn^{2+} < Fe^{2+}$; paramagnetic behaviour

39. Which of the following element is responsible for oxidation of water to O_2 in biological processes? *(1997)*

a. Cu b. Mo

c. Fe d. Mn

40. The lanthanide contraction is responsible for the fact that: *(1997)*

a. Zr and Hf have about the same radius

b. Zr and Zn have the same oxidation state

c. Zr and Y have about the same radius

d. Zr and Nb have similar oxidation state.

41. A transition element *X* has a configuration $[Ar]3d^4$ in its + 3 oxidation state. Its atomic number is: *(1996)*

a. 22 b. 19

c. 25 d. 26

42. When calomel reacts with NH_4OH, we get: *(1996)*

a. Hg_2O b. HgO

c. $HgNH_2Cl$ d. NH_2–Hg–Hg–Cl

43. The electronic configuration of transition elements is exhibited by: *(1996)*

a. ns^1 b. ns^2np^5

c. $ns^2\,(n-1)d^{1-10}$ d. $ns^2\,(n-1)d^{10}$

44. The mercury is the only metal which is liquid at 0°C. This is due to its: *(1995)*

a. High vapour pressure b. Weak metallic bond

c. High ionization energy d. Both (b) and (c)

45. The transition elements have a general electronic configuration: [MR*] *(1991)*

a. $ns^2\ np^6\ nd^{1-10}$ b. $(n-1)\ d^{1-10},\ ns^{0-2},\ np^{0-6}$

c. $(n-1)\ d^{1-10},\ ns^{1-2}$ d. $nd^{1-10}\ ns^{-2}$

46. Photographic films and plates have an essential ingredient of: *(1989)*

a. Silver nitrate b. Silver bromide

c. Sodium chloride d. Oleic acid

47. A blue colouration is not obtained when: *(1989)*

a. Ammonium hydroxide dissolves in copper sulphate

b. Copper sulphate solution reacts with $K_4[Fe(CN)_6]$

c. Ferric chloride reacts with sodium ferrocyanide

d. Anhydrous $CuSO_4$ is dissolved in water

48. The electronic configurations of four elements are given below. Which element does not belong to the same family as others? *(1989)*

a. $[Xe]4f^{14}\ 5d^{10}\ 6s^2$ b. $[Kr]4d^{10}\ 5s^2$

c. $[Ne]3s^2\ 3p^5$ d. $[Ar]3d^{10}\ 4s^2$

49. Hypo is used in photography to: *(1988)*
a. Reduce AgBr grains to metallic silver
b. Convert metallic silver to silver salt
c. Remove undecomposed silver bromide as a soluble complex
d. Remove reduced silver

Compounds of Transition Elements

50. Which of the following statements are INCORRECT? *(2023)*
A. All the transition metals except scandium form MO oxides which are ionic.
B. The highest oxidation number corresponding to the group number in transition metal oxides is attained in Sc_2O_3 to Mn_2O_7.
C. Basic character increases from V_2O_3 to V_2O_4 to V_2O_5.
D. V_2O_4 dissolves in acids to give VO_4^{3-} salts.
E. CrO is basic but Cr_2O_3 is amphoteric.
Choose the correct answer from the options given below:
a. B and C only b. A and E only
c. B and D only d. C and D only

51. In the neutral or faintly alkaline medium, $KMnO_4$ oxidises iodide into iodate. The change in oxidation state of manganese in this reaction is from **[MR*]** *(2022)*
a. +6 to +5 b. +7 to +4
c. +6 to +4 d. +7 to +3

52. Identify the incorrect statement. **[MR*]** *(2020)*
a. The transition metals and their compounds are known for their catalytic activity due to their ability to adopt multiple oxidation states and to form complexes.
b. Interstitial compounds are those that are formed when small atoms like H, C or N are trapped inside the crystal lattices of metals.
c. The oxidation states of chromium in CrO_4^{2-} and $Cr_2O_7^{2-}$ are not the same.
d. $Cr^{2+}(d^4)$ is a stronger reducing agent than $Fe^{2+}(d^6)$ in water.

53. The manganate and permanganate ions are tetrahedral, due to: **[MR*]** *(2019)*
a. The p-bonding involves overlap of p-orbitals of oxygen with d-orbitals of manganese
b. There is no p-bonding
c. The p-bonding involves overlap of p-orbitals of oxygen with p-orbitals of manganese
d. The p-bonding involves overlap of d-orbitals of oxygen with d-orbitals of manganese

54. Which one of the following ions exhibits d-d transition and paramagnetism as well? *(2018)*
a. CrO_4^{2-} b. $Cr_2O_7^{2-}$
c. MnO_4^{2-} d. MnO_4^-

55. Name the gas that can readily decolourise acidified $KMnO_4$ solution: *(2017-Delhi)*
a. P_2O_5 b. CO_2
c. SO_2 d. NO_2

56. Which one of the following statements is correct when SO_2 is passed through acidified $K_2Cr_2O_7$ solution? **[MR*]** *(2016-I)*
a. SO_2 is reduced
b. Green $Cr_2(SO_4)_3$ is formed
c. The solution turns blue
d. The solution is decolourised

57. Assuming complete ionisation, same moles of which of the following compounds will require the least amount of acidified $KMnO_4$ for complete oxidation? *(2015 Re)*
a. $Fe(NO_2)_2$ b. $FeSO_4$
c. $FeSO_3$ d. FeC_2O_4

58. Which of the statements is not true? *(2012 Pre)*
a. $K_2Cr_2O_7$ solution becomes yellow on increasing the pH beyond 7
b. On passing H_2S through acidified $K_2Cr_2O_7$ solution, a milky colour is observed
c. $Na_2Cr_2O_7$ is preferred over $K_2Cr_2O_7$ in volumetric analysis
d. $K_2Cr_2O_7$ solution in acidic medium is orange

59. Acidified $K_2Cr_2O_7$ solution turns green when Na_2SO_3 is added to it. This is due to the formation of: *(2011 Pre)*
a. $CrSO_4$ b. $Cr_2(SO_4)_3$
c. CrO_4^{2-} d. $Cr_2(SO_3)_3$

60. The number of moles of $KMnO_4$ that will be needed to react with one mole of sulphite ion in acidic solution is: **[MR*]** *(2007)*
a. 4/5 b. 2/5
c. 1 d. 3/5

61. The number of moles of $KMnO_4$ reduced by one mole of KI in alkaline medium is: *(2005)*
a. 2/5 b. 5
c. 1 d. 2

62. Which of the following is used in the preparation of chlorine? *(1999)*
a. Only MnO_2 b. Only $KMnO_4$
c. Both MnO_2 and $KMnO_4$ d. Either MnO_2 and $KMnO_4$

63. $K_2Cr_2O_7$ on heating with aqueous NaOH gives: *(1997)*
a. $Cr_2O_7^{2-}$ b. $Cr(OH)_2$
c. CrO_4^{2-} d. $Cr(OH)_3$

64. $KMnO_4$ reacts with oxalic acid according to the equation
$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$
Here 20 mL of 0.1 M $KMnO_4$ is equivalent to *(1996)*
a. 50 mL of 0.5 M $C_2H_2O_4$
b. 20 mL of 0.1 M $C_2H_2O_4$
c. 20 mL of 0.5 M $C_2H_2O_4$
d. 50 mL of 0.1 M $C_2H_2O_4$

65. The oxidation state of Cr in $K_2Cr_2O_7$ is: *(1988)*

a. +5 b. +3

c. +6 d. +7

Inner Transition Elements (Lanthanoids and Actinoids)

66. Given below are two statements : one is labelled as **Assertion (A)** and the other is labelled as **Reason (R)**.

Assertion (A): Ionisation enthalpies of early actinoids are lower than for early lanthanoids.

Reason (R): Electrons are entering 5f orbitals in actinoids which experience greater shielding from nuclear charge.

In the light of the above statements, choose the **correct** answer from the options given below: *(2023-Manipur)*

a. **(A)** is true but **(R)** is false.

b. **(A)** is false but **(R)** is true.

c. Both **(A)** and **(R)** are true and **(R)** is the correct explanation of **(A)**.

d. Both **(A)** and **(R)** are true but **(R)** is **not** the correct explanation of **(A)**.

67. Decrease in size from left to right in actinoid series is greater and gradual than that in lanthanoid series due to: *(2022 Re)*

a. 5*f* orbitals have greater shielding effect

b. 4*f* orbitals are penultimate

c. 4*f* orbitals have greater shielding effect

d. 5*f* orbitals have poor shielding effect

68. Gadolinium has a **low** value of third ionisation enthalpy because of **[MR*]** *(2022)*

a. high basic character b. small size

c. high exchange enthalpy d. hight electronegativity

69. The incorrect statement among the following is: **[MR*]** *(2021)*

a. Most of the trivalent Lanthanoid ions are colorless in the solid state

b. Lanthanoids are good conductors of heat and electricity

c. Actinoids are highly reactive metals, especially when finely divided

d. Actinoid contraction is greater for element to element than Lanthanoid contraction

70. Identify the incorrect statement from the following: **[MR*]** *(2020-Covid)*

a. Lanthanoids reveal only +3 oxidation state.

b. The lanthanoid ions other than the f^0 type and the f^{14} type are all paramagnetic.

c. The overall decreases in atomic and ionic radii from lanthanum to lutetium is called lanthanoid contraction.

d. Zirconium and Hafnium have identical radii of 160 pm and 159 pm, respectively as a consequence of lanthanoid contraction.

71. Match the element in Column-I with that in Column-II. *(2020-Covid)*

Column-I		Column-II	
A.	Copper	i.	Non-metal
B.	Fluorine	ii.	Transition metal
C.	Silicon	iii.	Lanthanoid
D.	Cerium	iv.	Metalloid

Select the correct option:

a.	A-i	B-ii	C-iii	D-iv
b.	A-ii	B-iv	C-i	D-iii
c.	A-ii	B-i	C-iv	D-iii
d.	A-iv	B-iii	C-i	D-ii

72. The reason for greater range of oxidation states in actinoids is attributed to: *(2017-Delhi)*

a. 4*f* and 5*d* levels being close in energies

b. The radioactive nature of actinoids

c. Actinoid contraction

d. 5*f*, 6*d* and 7*s* levels having comparable energies

73. Which one of the following statements related to lanthanons is incorrect? *(2016 - II)*

a. All the lanthanons are much more reactive than aluminium

b. Ce(+4) solutions are widely used as oxidizing agent in volumetric analysis

c. Europium shows +2 oxidation state.

d. The basicity decreases as the ionic radius decreases from Pr to Lu.

74. The electronic configurations of Eu (Atomic Number 63) Gd (Atomic Number 64) and Tb (Atomic Number 65) are: **[MR*]** *(2016-I)*

a. $[Xe]4f^76s^2$, $[Xe]4f^75d^16s^2$ and $[Xe]4f^96s^2$

b. $[Xe]4f^76s^2$, $[Xe]4f^8\ 6s^2$ and $[Xe]4f^8\ 5d^16s^2$

c. $[Xe]4f^6\ 5d^16s^2$, $[Xe]4f^7\ 5d^16s^2$ and $[Xe]4f^9\ 5d^16s^2$

d. $[Xe]4f^6\ 5d^16s^2$, $[Xe]4f^7\ 5d^16s^2$ and $[Xe]4f^8\ 5d^16s^2$

75. Gadolinium belongs to 4f series. Its atomic number is 64. Which of the following is the correct electronic configuration of gadolinium? *(2015 Re)*

a. $[Xe]4f^65d^26s^2$ b. $[Xe]4f^86d^2$

c. $[Xe]4f^95s^1$ d. $[Xe]4f^75d^16s^2$

76. Reason of lanthanoid contraction is: *(2014)*

a. Increasing nuclear charge

b. Decreasing nuclear charge

c. Decreasing screening effect

d. Negligible screening effect of '*f*' orbitals

77. Which of the following lanthanoid ions is diamagnetic? (Atomic Number Ce = 58, Sm = 62, Eu = 63, Yb = 70) *(2013)*

a. Ce^{2+} b. Sm^{2+}

c. Eu^{2+} d. Yb^{2+}

78. Which of the following exhibits only + 3 oxidation state? *(2012 Mains)*

a. U b. Th

c. Ac d. Pa

79. Which of the following oxidation states is the most common among the lanthanoids? *(2010 Mains)*
a. 4 b. 2
c. 5 d. 3

80. Identify the incorrect statement among the following: *(2007)*
a. Lanthanoid contraction is the accumulation of successive shrinkages.
b. As a result of lanthanoid contraction, the properties of 4d series of the transition elements have no similarities with the 5d series of elements.
c. Shielding power of 4f electrons is quite weak.
d. There is a decrease in the radii of the atoms or ions as one proceeds from La to Lu.

81. More number of oxidation states are exhibited by the actinoids than by the lanthanoids. The main reason for this is: [MR*] *(2006)*
a. More energy difference between 5f and 6d orbitals than that between 4f and 5dorbitals
b. Lesser energy difference between 5f and 6d orbitals than that between 4f and 5d orbitals
c. Greater metallic character of the lanthanoids than that of the corresponding actinoids
d. More active nature of the actinoids

82. The main reason for larger number of oxidation states exhibited by the actinides than the corresponding lanthanides, is: *(2005)*
a. Lesser energy difference between 5*f* and 6*d* orbitals than between 4f and 5*d* orbitals
b. Larger atomic size of actinides than the lanthanides
c. More energy difference between 5*f* and 6*d* orbitals than between 4*f* and 5*d* orbitals
d. Greater reactive nature of the actinides than the lanthanides

83. Lanthanoids are: *(2004)*
a. 14 elements in the seventh period (atomic number = 90 to 103) that are filling 5f sublevel.
b. 14 elements in the sixth period (atomic number = 58 to 71) that are filling 4f sublevel
c. 14 elements in the seventh period (atomic number = 58 to 71) that are filling 4f sublevel
d. 14 elements in the sixth period (atomic number = 90 to 103) that are filling 4f sublevel

84. The correct order of ionic radii of Y^{3+}, La^{3+}, Eu^{3+} and Lu^{3+} is: [MR*] *(2003)*
(Atomic numbers Y = 39, La = 57, Eu = 63, Lu = 71)
a. $Y^{3+} < La^{3+} < Eu^{3+} < Lu^{3+}$ b. $Y^{3+} < Lu^{3+} < Eu^{3+} < La^{3+}$
c. $Lu^{3+} < Eu^{3+} < La^{3+} < Y^{3+}$ d. $La^{3+} < Eu^{3+} < Lu^{3+} < Y^{3+}$

85. General electronic configuration of lanthanides is: *(2002)*
a. $(n-2)\,f^{1-14}\,(n-1)\,s^2p^6d^{0-1}\,ns^2$
b. $(n-2)\,f^{10-14}\,(n-1)\,d^{0-1}\,ns^2$
c. $(n-2)\,f^{10-4}\,(n-1)\,d^{10}\,ns^2$
d. $(n-2)\,d^{0-1}\,(n-1)\,f^{1-14}\,ns^2$

86. Which of the following statement is not correct? [MR*] *(2001)*
a. $La(OH)_3$ is less basic than $Lu(OH)_3$
b. In Lanthanide series, ionic radius of Ln^{+3} ions decreases
c. La is actually an element of transition series rather Lanthanide
d. Atomic radius of Zn and Hf are same because of Lanthanide contraction

87. Which one of the following elements shows maximum number of different oxidation states in its compounds? *(1998)*
a. Eu b. La
c. Gd d. Am

88. The electronic configuration of gadolinium (Atomic Number = 64) is: *(1997)*
a. [Xe] $4f^8\,5d^0\,6s^2$ b. [Xe] $4f^6\,5d^2\,6d^2$
c. [Xe] $4f^8\,5d^0\,6s^2$ d. [Xe] $4f^7\,5d^1\,6s^2$

89. Which of the following statement concerning lanthanide elements is false? *(1994)*
a. All lanthanides are highly dense metals.
b. More characteristic oxidation state of lanthanide elements is +3.
c. Lanthanides are separated from one another by ion exchange method.
d. Ionic radii of trivalent lanthanides steadily increases with increase in the atomic number

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Answer Key

1. (d)	2. (c)	3. (a)	4. (b)	5. (a)	6. (a)	7. (a)	8. (d)	9. (b)	10. (d)
11. (b)	12. (a)	13. (b)	14. (d)	15. (d)	16. (d)	17. (b)	18. (b)	19. (c)	20. (a)
21. (d)	22. (b)	23. (b)	24. (d)	25. (a)	26. (d)	27. (a)	28. (c)	29. (d)	30. (d)
31. (d)	32. (a)	33. (c)	34. (b)	35. (b)	36. (b)	37. (d)	38. (d)	39. (d)	40. (a)
41. (c)	42. (c)	43. (c)	44. (d)	45. (c)	46. (b)	47. (b)	48. (c)	49. (c)	50. (d)
51. (b)	52. (c)	53. (a)	54. (c)	55. (c)	56. (b)	57. (b)	58. (c)	59. (b)	60. (b)
61. (d)	62. (c)	63. (c)	64. (d)	65. (c)	66. (c)	67. (d)	68. (c)	69. (a)	70. (a)
71. (c)	72. (d)	73. (a)	74. (a)	75. (d)	76. (d)	77. (d)	78. (c)	79. (d)	80. (b)
81. (b)	82. (a)	83. (b)	84. (b)	85. (a)	86. (a)	87. (d)	88. (d)	89. (d)	

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Explanations

1. **(d)** The greater stability of Cu^{2+} (aq) rather than Cu^{+} (aq) is due to the much more negative $\Delta_{hyd}H$ of Cu^{2+}(aq) than Cu^{+}, which more than compensates for the second ionisation enthalpy of Cu.

2. **(c)** All the oxides given in option (c) are acidic oxides.

3. **(a)** Cr : [Ar] $3d^5 4s^1$

   Cr^{2+}: [Ar]$3d^4$

   Cr^{+2} is reducing in nature as its configuration change from d^4 to more stable configuration d^3 (t_{2g}^3)

   Mn : [Ar]$3d^5 4s^2$

   Mn^{+2}: [Ar] $3d^5$ (extra stability)

   $\therefore$ Mn^{2+} is oxidising in nature.

   $\therefore$ Statement I is incorrect

   Sc : [Ar]$3d^1 4s^2$

   Sc^{+3} : [Ar]

   diamagnetic – repelled by magnetic field

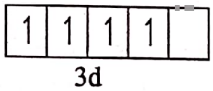
   Statement (II) is correct.

4. **(b)** The almost identical radii of Zr (160 pm) and Hf (159 pm) is a consequence of the lanthanoid contraction which causes the radii of third transition series member to very similar to corresponding member of second series.

   Lanthanide contraction is the abnormal decrease in the ionic and the atomic radius with the increase in the atomic number. The cause the lanthanide contraction is the poor shielding effect of the 4*f*-orbital due to which the elections in the *s*-orbital gets attracted more towards the nucleus, which leads to the decrease in size of the atom.

5. **(a)** Electronic configuration of Cr [Ar]$3d^5$ $4s^1$

   The electronic configuration of Cr^{2+} [Ar]$3d^4$

   So, Number of unpaired electron is 4

   Spin only magnetic moment $\mu = \sqrt{n(n+2)}$

   $= \sqrt{4(4+2)}$

   $= 4.9$ B.M

6. **(a)**

   (A) The electronic configuration of Mn is [Ar] $3d^5 4s^2$.

   Hence, Manganese shows maximum number of oxidation states i.e., (+2 to +7)

   (B) Zinc atom has completely filled *d*-orbitals in its ground state as well as in its oxidized state, thus it is not regarded as a transition element.

   (C) The electronic configuration of Sc [Ar]$3d^1 4s^2$.

   Scandium shows only one oxidation state i.e., +3 oxidation state because after losing two 4s electrons, the configuration is $3d^1$ which is not much stable, therefore it loses it and thus, shows only +3.

   (D) Disproportionation reaction are those reactions in which only one specie in reactant side undergoes oxidation as well as reduction. Here, Cu^{+} undergoes disproportionation reaction in aqueous solution.

   The reaction takes place as:

   $2Cu^{+}(aq) \rightarrow Cu^{2+}(aq) + Cu(s)$

   Thus, from the reaction, it can be seen that Cu^{+} changes to Cu^{2+} by losing one e^{-}(oxidation) and changes to Cu by gaining one e^{-}(reduction).

7. **(a)** Co^{3+} = [Ar] $3d^6$, Unpaired electron (n) = 4

   Spin magnetic moment = $4\sqrt{4(4+2)} = \sqrt{24}$ B.M

   Cr^{3+} = [Ar] $3d^3$, Unpaired electron (n) = 3

   Spin magnetic moment = $\sqrt{3(3+2)} = \sqrt{15}$ B.M

   Fe^{3+} = [Ar] $3d^5$, Unpaired electron (n) = 5

   Spin magnetic moment = $\sqrt{5(5+2)} = \sqrt{35}$ B.M

   Ni^{2+} = [Ar] $3d^8$, Unpaired electron (n) = 2

   Spin magnetic moment = $\sqrt{2(2+2)} = \sqrt{8}$ B.M

8. **(d)** In a solution containing $HgCl_2$, I_2 and I^-, both $HgCl_2$ and I_2 compete for I^-.

   Since formation constant of $[HgI_4]^{2-}$ is 1.9×10^{30} which is very large as compared with I_3^- ($K_f = 700$)

   $\therefore$ I^- will preferentially combine with $HgCl_2$.

   $HgCl_2 + 2I^- \rightarrow HgI_2 \downarrow + 2Cl^-$

   Red ppt

   $HgI_2 + 2I^- \rightarrow [HgI_4]^{2-}$

   soluble

9. **(b)** (a) When iron nails are immersed in $CuSO_4$ solution, the iron element being stronger than copper displaces it forms ferrous sulphate due to which decolourization of $CuSO_4$ occurs. The reaction occurs as:

   $CuSO_4 + Fe \rightarrow FeSO_4 + Cu$

   Since, oxidation state of Fe is increased from 0 to 2+, indicating this an oxidation reaction.

   (b) For the formation of $Fe(CO)_5$ the reaction occurs as.

   $Fe + 5CO \rightarrow Fe(CO)_5$

   The oxidation state of iron in the reactant zero and in the product also zero. So, there is no increase in oxidation state of iron, hence not an oxidation reaction.

   (c) The reaction takes place as:

   $3Fe(s) + 4H_2O(steam) \rightarrow Fe_3O_4(s) + H_2(g)$

   Here, iron (Fe) is undergoing oxidation as its oxidation state changes from zero to +8/3.

   (d) Iron in presence of O_2 forms Iron oxide.

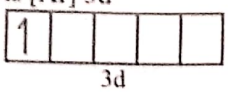
   $4Fe + 3O_2 + 2x \cdot H_2O \rightarrow 2Fe_2O_3 \cdot xH_2O$

   (Rust)

   Since, there is addition of oxygen, therefore, it is an oxidation reaction.

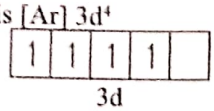
10. **(d)** The formula for spin only magnetic moment, μ is $\mu = \sqrt{n(n+2)}$, n is the number of unpaired electron.

(a) For Ti^{3+}, the electronic configuration is [Ar] $3d^1$



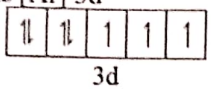
$\mu = \sqrt{1(1+2)} = \sqrt{3} = 1.73$ B.M

(b) For Cr^{2+}, the electronic configuration is [Ar] $3d^4$



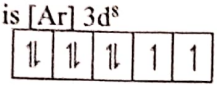
$\mu = \sqrt{4(4+2)} = \sqrt{24} = 4.9$ B.M

(c) For Co^{2+}, the electronic configuration is [Ar] $3d^7$



$\mu = \sqrt{3(3+2)} = \sqrt{15} = 3.87$ B.M

(d) For. Ni^{2+}, the electronic configuration is [Ar] $3d^8$



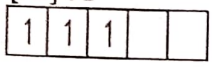
$\mu = \sqrt{2(2+2)} = 2.84$ B.M.

11. **(b)** Zr (40) and Hf (72) will have same atomic size because of lanthanoid contraction and poor shielding effect.

12. **(a)**

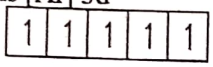
(a) For Ni^{2+}, $\mu = \sqrt{2(2+2)} = 2.84$ B.M

(b) for Cr^{3+}, the electronic configuration is [Ar] $3d^3$



$\mu = \sqrt{3(3+2)} = \sqrt{15} = 3.87$ B.M

(c) For Mn^{2+}, the electronic configuration is [Ar] $3d^5$



$\mu = \sqrt{5(5+2)} = \sqrt{35} = 5.91$ B.M

(d) Ti^{3+}, $\mu = \sqrt{1(1+2)} = \sqrt{3} = 1.73$ B.M

13. **(b)** Interstitial compounds are those which are formed when small atoms like H, C, N are trapped inside the crystal lathies of metals. And, generally they are inert in nature. They have high M.P than corresponding pure metals. They also retain metallic conductivity and they are much harder than the pure metal.

14. **(d)** While plotting the melting point curve, a significant decrease is observed while moving from Mn to Fe so, Ti < V < Mn is not the correct order, Cr in its period has highest melting point.

Order of mp is: Ti < V < Mn < Cr

15. **(d)** *d*-orbital atom or transition elements are good catalysts because they can show variable oxidation states.

16. **(d)** In the electrochemical series, Cu is below hydrogen. Hence, it has positive value of standard reduction potential.

The standard reduction potentials for the elements is given below:

Element	Co	Ni	Cu	Fe
$E^{\circ}_{M^{2+}/M}$	− 0.28	− 0.25	+ 0.34	− 0.44

17. **(b)** Invar ⇒ Ni(metal) + Fe(metal)

Steel ⇒ C(non-metal) + Fe(metal)

Bell ⇒ Cu(metal) + Sn(metal) + Fe(metal)

Bronze ⇒ Cu(metal) + Sn(metal)

18. **(b)** Mn^{2+} being the most stable because after losing 2 electr it has now half filled stable configuration.

Hence, stability of +2 oxidation state becomes:

Mn > Fe > Cr > Co

19. **(c)** Color is exhibited in the solution when ionic species w unpaired electron is present. Among the 4 options,

Sc^{3+} (Z = 21), La^{3+} (Z = 57) & Lu^{3+} (Z = 71) gains noble g configuration & will have colorless solutions.

Whereas Ti^{3+} have 1 unpaired electron exhibits colour to t solution.

20. **(a)** (Atomic number: Mn = 25, Fe = 26, Co = 27, Ni = 28) Co^{3+} has electronic configuration as [Ar] $3d^6$.

21. **(d)** Zr^{+4} & Hf^{+4} has same ionic size because lanthano contraction (inner pair effect) dominates.

22. **(b)** Among 4 options the element with outer-orbi configuration as $3d^5 4s^2$ is Mn which will exhibit more numb of oxidation states.

23. **(b)** As per the 2nd ionization enthalpy where, by removing 2 electron from Cr results into an half-filled stable structu with electronic configuration as

Cr (24) → [Ar] $3d^5$ $4s^1$

Cr^+ (23) → [Ar] $3d^5$

So, order for 2nd ionization enthalpy becomes:

Cr > Mn > V > Ti

24. **(d)** Chromium ion (Cr^{3+}) in + 3 oxidation state is most stabl because it has *d*-electronic configuration half-filled. Hence is most stable in aqueous solution.

25. **(a)** Color in solution is imparted because of absorbance light (visible) range by the unpaired electron of ions preser in solution. Ni^{2+} has 2 unpaired electron & Ti^{3+} has 1 unpaire electron. Rest in all 4 options none of two ions have unpaire electron in ionic state.

26. **(d)** Manganese (Mn) after losing 2 electron becomes Mn^{2+} has now reached half – filled stable 3*d* configuration. Amon 4 options Mn^{2+} will have highest 3rd ionization enthalpy a it would be very difficult to extract electron from a stabl system.

27. **(a)** Sc^{3+} has no unpaired electron in its outermost *d*-orbita thus it will impart no color to the solution.

28. **(c)** $Ti_{22} = 3d^2 4s^2$; $Ti^{2+} = 3d^2$

$V_{23} = 3d^3 4s^2$; $V^{3+} = 3d^2$

$Cr_{24} = 3d^4 4s^2$; $Cr^{4+} = 3d^2$

$Mn_{25} = 3d^5 4s^2$; $Mn^{5+} = 3d^2$

29. **(d)** A binary compound is one made of 2 different element.

Since, Fe can exist in + 2 & + 3 oxidation state therefore it can form more than one binary compound with chlorine Eg. $FeCl_2$, $FeCl_3$.

30. **(d)** The catalytic activity of transitional metals is due to thei variable oxidation states.

31. (d) Oxidation states of transition metal in low oxidation states +2 & +3 (MO, M_3O_4 & M_2O_3) are generally basic except Cr_2O_3 which is amphoteric in nature. Basic character decreases with increases in atomic number.

32. (a) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$ has last electron of atom filled in d sub-shell as $3d^3$. Thus, this element belong to d-block of the periodic table with group no. V.

33. (c) Each of the element in group III B to VII B can show the maximum oxidation state equal to its group no.

Mn is in group 7, and shows a maximum oxidation state of +7 because it has 5 unpaired electron in 3d and also contains 2 electron 4s sub-shell.

34. (b) The most convenient method to protect the bottom of the ship made of iron is white tin platting preventing the build up of barnacles.

35. (b) $_{21}Sc \rightarrow 3d^1, 4s^2$ (valence shell)

For Sc^{3+}, the electronic configuration is $3d^0$, thus, there is no unpaired 'd' electrons, therefore it is colourless ion in its solution.

36. (b) Manganese (Mn) shows maximum number of oxidation states because it has 5 unpaired electron in 3d & also contains 2 electron in 4s sub-shell

+2, +3, +4, +5, +6, +7

While other metals have

Cr = +2, +3, +4, +5, +6

Fe = +2, +3

Ti = +2, +3, +4

37. (d) $Cr^{3+} = 1s^2, 2s^2\ 2p^6, 3s^2\ 3p^6\ 3d^3$ (colour)

$Zn^{2+} = 1s^2, 2s^2, 2p^6.\ 3s^2\ 3p^6\ 3d^{10}$ (colourless)

$Cu^{+} = 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}$ (colourless)

$Ti^{4+} = 1s^2, 2s^2\ 2p^6, 3s^2\ 3p^6$ (colourless)

(Colour is produced due to presence of unpaired electron)

38. (d) More the number of unpaired elections, more is paramagnetic behaviour.

For V^{2+}, n = 3 as its electronic configuration is $3d^3$

For Cr^{2+}, n = 4 as its electronic configuration is $3d^4$

For Mn^{2+}, n = 5 as its electronic configuration is $3d^5$

For Fe^{2+}, n = 4 as its electronic configuration is $3d^6$

Hence, the correct order is $Mn^{2+} > Fe^{2+} > Cr^{2+} > V^{2+}$

39. (d) Mn is responsible for oxidation of water to O_2 in biological processes.

40. (a) Due to lanthanide contraction, the elements of second and third *i.e.* Zr and Hf transition series resemble more with each other than the elements of first and second transition series.

41. (c) It is the configuration of metal ion. The metal atom will have three more electrons. Therefore, the atomic number of the metal = (18) + 4+ 3 = 25.

42. (c) When calomel reacts with NH_4OH, it turns black due to the formation of a mixture of mercury and ammonium basic mercury (II) chloride.

$Hg_2Cl_2 + 2\,NH_4OH \rightarrow NH_4Cl + 2H_2O + Hg$
(calomel) $+ HgNH_2Cl$

43. (c) General electronic configuration of transition elements is $ns^{1-2}\,(n-1)d^{1-10}$

44. (d) Very high ionization energy of Hg makes it difficult for electrons to participate in metallic bonding. Mercury has fully filled d–orbitals,d–d overlap cannot take place. Again, this cause weak metallic bonds, due to which mercury is a liquid at 0°C.

45. (c) The general electronic configuration of transition elements is $(n-1)d^{1-10}\,ns^{1-2}$

46. (b) AgBr is highly photosensitive and is used as an ingredient for photographic films and plates.

47. (b) $2CuSO_4 + K_4[Fe(CN)_6] \rightarrow Cu_2[Fe(CN)_6] + 2K_2SO_4$
chocolate ppt.

48. (c) $[Ne]3s^2 3p^5$ is the electronic configuration of a *p*-block element whereas other configurations are those of *d*-block elements.

49. (c) Undecomposed AgBr forms a soluble complex with hypo and the reaction is given as:

$AgBr + 2Na_2S_2O_3 \rightarrow Na_3[Ag(S_2O_3)_2] + NaBr$
soluble complex

50. (d) The highest oxidation number corresponding to the group number in transition metal oxides is attained in Sc_2O_3 to Mn_2O_7.

CrO is basic but Cr_2O_3 is amphoteric.

Note:

All the transition metals except scandium form MO oxides which are ionic (Only for 3d series, this statement is true)

Hence, (A), (C) and (D) are incorrect. But not given in the options.

51. (b) $\overset{+7}{K}\overset{+7}{Mn}O_4 + I^- \xrightarrow[\text{or weakly alkaline medium}]{\text{Neutral}} \overset{+4}{Mn}O_2 + IO_3^-$

Therefore, the change in oxidation state of Mn is from + 7 to + 4.

52. (c) Let 'x' be the oxidation state of Cr.

The oxidation state of Cr in CrO_4^{2-} is

$x + 4(-2) = -2$

$\Rightarrow x = +6$

The oxidation state of Cr in $Cr_2O_7^{2-}$ ion is

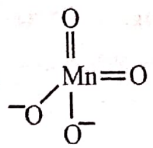
$2x + 7(-2) = -2$

$\Rightarrow x = +6$

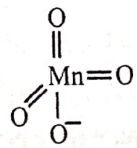
Hence, they are same.

53. (a)

• Manganate (MnO_4^{2-}):



• Permanganate (MnO_4^-):



$Mn_{25} - 3d^5 4s^2$

Both are tetrahedral due to d's hybridisation and there will be overlapping between p-orbital of oxygen and d-orbital of Mn.

54. **(c)** CrO_4^{2-}

$x + 4(-2) = -21$

$x = -2 + 8 = +6$

Cr: [Ar]$3d^5 4S$

Cr^{6+}: [Ar]

Hence there is no unpaired e^-, so it is diamagnetic

$Cr_2O_7^{2-} \rightarrow Cr^{6+} = [Ar]$

Unpaired electron (n) = 0; Diamagnetic

$MnO_4^{2-} = Mn^{6+} = [Ar]\ 3d^1$

Unpaired electron (n) = 1; Paramagnetic

$MnO_4^- = Mn^{7+} = [Ar]$; Diamagnetic

Since, MnO_4^{2-} consists of unpaired e^-, hence,d-d transitions will occur in it.

55. **(c)** SO_2 is a gas that can readily decolourise acidified $KMnO_4$ solution.

The reaction take place as: $2KMnO_4 + 5O_2 + 2H_2O$

(Pink violet) ↓

$K_2SO_4 + 2MnSO_4 + 2H_2SO_4$

(Colourless)

Hence, it can be seen that pink violet colour of acidified $KMnO_4$ decolourise and the solution turns colourless.

56. **(b)** The reaction takes place as:

$K_2Cr_2O_7 + H_2SO_4 + 3SO_2 \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + H_2O$

It can be seen that orange colour solution due to $K_2Cr_2O_7$ turns green due to the formation of $Cr_2(SO_4)_3$. SO_2 is oxidised to as it changes its oxidation state from + 4 to + 6 in K_2SO_4 and $Cr_2(SO_4)_3$. Also solution is not decolourlise as it is green in colour.

57. **(b)** All of these compounds have the same positive ion, Fe^{2+}, which will get oxidised to Fe^{3+}. So, the compound, where the anion doesnot get oxidised by $KMnO_4$ would require the least amount to get oxidised completely.

$C_2O_4^{2-} \rightarrow CO_2$

$NO_2^- \rightarrow NO_3^-$

$SO_3^{2-} \rightarrow SO_4^{2-}$

Since SO_4^{2-} has S in highest oxidation state, therefore it cannot be oxidised, thus, $FeSO_4$ will require least amount to get oxidised completely as only Fe^{2+} will convert into Fe^{3+}.

58. **(c)** $K_2Cr_2O_7$ is usually preferred over $Na_2Cr_2O_7$ because of better colour change in the reaction.

59. **(b)** $K_2Cr_2O_7 + 3Na_2SO_3 + 4H_2SO_4 \rightarrow 3Na_2SO_4 + K_2SO_4 + Cr_2(SO_4)_3 + 4H_2O$

(green)

60. **(b)** The balance chemical equation is:

$2MnO_4^- + 6H^+ + 5SO_3^{2-} \rightarrow 2Mn^{2+} + 5SO_4^{2-} + 3H_2O$

From the equation, it is clear that, 2 moles of $MnO_4^{\ominus}$ requires 5 moles of SO_3^{2-}.

Thus, 1 mole of sulphite ion in acidic solution, requires $\frac{2}{5}$ moles of MnO_4^-.

61. **(d)** The reaction can be represented as

$2\ KMnO_4 + KI + H_2O \rightarrow KIO_3 + 2\ MnO_2 + 2KOH$

According to reaction, 2 moles of $KMnO_4$ will be reduced by 1 mole of KI.

62. **(c)** $MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$

$2KMnO_4 + 16\ HCl \rightarrow 2KCl + 2\ MnCl_2 + 8H_2O + 5Cl_2$

63. **(c)** $K_2Cr_2O_7 + 2NaOH \rightarrow 2Na_2CrO_4 + H_2O$

or $Cr_2O_7^{2-} + 2OH^- \rightarrow 2CrO_4^{2-} + H_2O$

64. **(d)** $2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$

$\therefore$ 2 moles of $MnO_4^- \equiv 5$ moles of $C_2O_4^{2-}$

20 mL of 0.1 M $KMnO_4$ = 2 mol of $KMnO_4$ Also, 50 mL of 0.1 M $C_2H_2O_4$ = 5 mole of $C_2O_4^{2-}$ Therefore, these are equivalent. ($\because$ Number of moles = M × V)

65. **(c)** Oxidation state of Cr in $K_2Cr_2O_7$ is

$2 + 2x - 14 = 0$

$\therefore\ 2x = 14 - 2 \Rightarrow 12$

$\therefore\ x = +6.$

66. **(c)** Both (A) and (R) are correct and reason is the correct explanation of Assertion.

67. **(d)** The shielding effect of 5*f* orbitals is poor because of their larger size as compared to 4*f* orbitals.

68. **(c)** The electronic configuration of *f*-block element Gd is

$_{64}Gd = [Xe]\ 6s^2\ 4f^7\ 5d^1$

$Gd^{+2} = [Xe]\ 4f^7\ 5d^1$

After losing 5*d* electron, 4*f* has maximum exchange energy so Gd has low value of third ionisation energy.

69. **(a)** (a) Most of the trivalent lanthanoids ions are coloured in a solid state due to the presence of f-electrons.

(b) Lanthanoids are inner transition metals having typical metallic structures and hence, are good conductors of heat and electricity.

(d) The 5*f*-electrons of actinides are poorly shielded as compared to the 4*f*-electrons of lanthanoids, so effective nuclear change on 5*f*-electrons of the actinides are more hence, actinoid contraction is greater.

70. **(a)** Lanthanoids can also show +2 or +4 oxidation states in solution or in solid compounds.

Most common oxidation state of Lanthanoids is +3

71. **(c)**

A.	Copper	ii.	Transition metal
B.	Fluorine	i.	Non-metal
C.	Silicon	iv.	Metalloid
D.	Cerium	iii.	Lanthanoid

72. **(d)** 5*f*, 6*d*, 7*s* level having comparable energies. There is very less energy gap between them.

Thus, in actinides, the electrons can be removed from 5*f* as well as 6*d* and 7*s*, so more oxidation states are possible.

3. **(a)** (a) The valence *4f* orbitals are deep buried so they are not affected by the ligand field, so, lanthanides are less reactive than aluminum. Also lanthanides and aluminum are different block elements, so simply their reactivity cannot be compared, so it cannot be said that all lanthanons are much more reactive than aluminum.

(b) The most stable oxidation state shown by lanthanides is +3, so, Ce^{4+} easily reduces into Ce^{3+}. Hence, widely used as oxidising agent.

(c) From Pr to Lu, size of the lanthanides decreases so the Z_{eff} increases which makes then Ln—O bond strong, so the tendency to lose the OH^- decreases from Pr to Lu.

Hence, basicity decreases from Pr to Lu.

74. **(a)** Eu, Gd, Tb belongs to *4f* series.

Hence, the Electronic configuration of Eu, Gd and Tb are:

Eu = *[Xe] 4f⁷ 6s²* Gd = *[Xe] 4f⁷ 5d¹ 6s²*

Tb = *[Xe] 4f⁹ 6s²*

75. **(d)** Gadolinium belongs to 4f series.

The general electronic configuration for *f*-series is $[Xe](n-2)^{1-14}\,(n-1)d^{1-10}\,ns^2$.

Gd atomic number is 64. Hence, it's electronic configuration is $[Xe]\,4f^7 5d^1 6s^2$.

76. **(d)** Lanthanide contraction is the abnormal decrease in the ionic and the atomic radius with the increase in the atomic number. The cause of the lanthanide contraction is the poor shielding effect of the *4f*-orbital due to which the elections in the *s*-orbital gets attracted more towards the nucleus, which leads to the decrease in size of the atom.

77. **(d)** The electronic configurations are:

Ce: $[Xe]\,4f^1\,5d^1\,6s^2$

Ce^{2+}: $[Xe]\,4f^1\,5d^1$

Hence, it has unpaired electrons both in *4f* and *5d*, therefore, paramagnetic in nature.

Now, Sm: $[Xe]\,4f^6\,6s^2$

Sm^{2+}: $[Xe]\,4f^6$

Hence, it has unpaired electrons in *4f*, therefore, paramagnetic in nature.

Now, Eu: $[Xe]\,4f^7\,6s^2$

Eu^{2+}: $[Xe]\,4f^7$

Hence, it has unpaired elections in *4f*, therefore, paramagnetic in nature.

Yb (70) = $[Xe]\,4f^{14}\,5d^0\,6s^2$

Yb^{2+} = $[Xe]\,4f^{14}\,5d^0\,6s^0$

Yb^{2+} has no unpaired electron so, it is a diamagnetic species.

78. **(c)** U exhibits +3, +4, +5, +6

Th exhibits +3, +4

Ac exhibits + 3 only

Pa exhibits +3, +4, +5

79. **(d)** The common stable oxidation number of lanthanoid is +3 but +2 and +4 are also exhibited by some elements.

80. **(b)** There is a steady decrease in the radii as the atomic number of the lanthanide elements increases. For every additional proton added in nucleus the corresponding electron goes to *4f* subshell. The shape of *f*-orbital is very much diffused and they have poor shielding effect.

The effective nuclear charge increases, which causes the contraction in the size of electron charge cloud. This contraction in size is quite regular and known as lanthanoid contraction. The atomic radii of elements of 4d and 5d series come close as a result of lanthanide contraction, therefore the properties of 4d and *5d*-transition elements shows the similarities.

81. **(b)** Actinides have more oxidation state as compared to lanthanides because in actinides lesser energy difference is present between *5f* & *6d* orbitals as compared to *4f* & *5d* orbitals of lanthanides. Thus, in actinides, the electrons can be removed from *5f* as well as *6d*, so more oxidation states are possible.

82. **(a)** Actinides exhibits more oxidation states as compared to lanthanides because of lesser energy difference between *5f* & *6d* orbitals as compared to *4f* & *5d* orbitals.

83. **(b)** In periodic table, 6th period contain only 18 elements. 14 members of 4f series (atomic no = 58 to 71) are separately present in a horizontal row called the seventh period below the periodic table. These are called lanthanides.

84. **(b)** On going from La^{3+} to Lu^{3+}, the ionic radii shrinks from 1.15Å to 0.93Å (lanthanoid contraction). The radius of La^{3+} is also larger than that of Y^{3+} ion because it lies immediately above it in periodic table.

85. **(a)** The general electronic configuration of lanthanides is $(n-2)f^{1-14}\,(n-1)\,s^2p^6d^{0-1}\,ns^2$.

86. **(a)** $La(OH)_3$ is more basic than $Lu(OH)_3$. In lanthanoid, the basic character of hydroxides decreases as the ionic radius decreases.

87. **(d)** Oxidation state shown by element are as La = +3 Europium (Eu) and gadolinium (Gd) = +2 and +3 respectively, Americium (Am) = 2 + 3 + 4 + 5 and 6.

Am show maximum number of different oxidation state due to its large size and low ionisation energy.

88. **(d)** The electronic configuration of gadolinium is $[Xe]\,4f^7\,5d^1\,6s^2$.

89. **(d)** Ionic radii of trivalent lanthanides decreases with increase in atomic number.

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CHAPTER 6

Coordination Compounds

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Introduction and Werner's Theory of Coordination Compounds

1. Homoleptic complex from the following complexes is: [MR*] *(2023)*
   a. Triamminetriaquachromium (III) chloride
   b. Potassium trioxalatoaluminate (III)
   c. Diamminechloridonitrito – N- platinum(II)
   d. Pentaamminecarbonatocobalt (III) chloride

2. Which complex compound is most stable? *(2023)*
   a. $[Co(NH_3)_6]_2 (SO_4)_3$
   b. $[Co(NH_3)_4 (H_2O)Br] (NO_3)_2$
   c. $[Co(NH_3)_3 (NO_3)_3]$
   d. $[CoCl_2(en)_2]NO_3$

3. Which of the following forms a set of complex and a double salt, respectively ? [MR*] *(2023-Manipur)*
   a. $CuSO_4.5H_2O$ and $CuCl_2.4NH_3$
   b. $PtCl_2.2NH_3$ and $PtCl_4.2HCl$
   c. $K_2PtCl_2.2NH_3$ and $KAl(SO_4)_2.12H_2O$
   d. $NiCl_2.6H_2O$ and $NiCl_2(H_2O)_4$

4. Ethylene diaminetetraacetate (EDTA) ion is: *(2021)*
   a. Unidentate ligand
   b. Bidentate ligand with two "N" donor atoms
   c. Tridentate ligand with three "N" donor atoms
   d. Hexadentate ligand with four "O" and two "N" donor atoms

5. The correct order of the stoichiometries of AgCl formed when $AgNO_3$ in **excess** is treated with the complexes: $CoCl_3.6NH_3$, $CoCl_3.5NH_3$ $CoCl_3.4NH_3$ respectively is: [MR*] *(2017-Delhi)*
   a. 2AgCl, 3AgCl, 1AgCl
   b. 1AgCl, 3AgCl, 2AgCl
   c. 3AgCl, 1AgCl, 2AgCl
   d. 3AgCl, 2AgCl, 1AgCl

6. Cobalt(III) chloride forms several octahedral complexes with ammonia. Which of the following will not give test for chloride ions with silver nitrate at 25°C? *(2015)*
   a. $CoCl_3.4NH_3$
   b. $CoCl_3.5NH_3$
   c. $CoCl_3.6NH_3$
   d. $CoCl_3.3NH_3$

7. The sum of coordination number and oxidation number of the metal M in the complex $[M(en)_2(C_2O_4)]Cl$ (where en is ethylenediamine) is: *(2015 Re)*
   a. 6
   b. 7
   c. 8
   d. 9

8. $CuSO_4$ when reacts with KCN forms CuCN, which is insoluble in water. It is soluble in excess of KCN, due to formation of the following complex: *(2002)*
   a. $K_2[Cu(CN)_4]$
   b. $K_3[Cu(CN)_4]$
   c. $Cu(CN)_2$
   d. $Cu[KCu(CN)_4]$

9. Coordination number of Ni in $[Ni(C_2O_4)_3]^{-4}$ is: *(2001)*
   a. 3
   b. 6
   c. 4
   d. 2

10. A co-ordination complex compound of cobalt has the molecular formula containing five ammonia molecules, one nitro group and two chlorine atoms for one cobalt atom. One mole of this compound produces three mole ions in an aqueous solution. On reacting this solution with excess of $AgNO_3$ solution, we get two moles of AgCl precipitate. The ionic formula for this complex would be: *(1998)*
    a. $[Co(NH_3)_4 (NO_2)Cl] [NH_3Cl]$
    b. $[Co(NH_3) Cl] [Cl(NO_2)]$
    c. $[Co(NH_3)_5 (NO_2)] Cl_2$
    d. $[Co(NH_3)_5] [(NO_2)_2Cl_2]$

11. The coordination number and oxidation state of Cr in $K_3Cr(C_2O_4)_3$ are respectively: *(1995)*
    a. 3 and + 3
    b. 3 and 0
    c. 6 and + 3
    d. 4 and + 2

12. Which of the following ligands is expected to be bidentate? [MR*] *(1994)*
    a. CH_3NH_2
    b. $CH_3C \equiv N$
    c. Br
    d. $C_2O_4^{2-}$

Nomenclature & Isomerism in Coordination Compounds

13. Type of isomerism exhibited by compounds $[Cr(H_2O)_6]Cl_3$, $[Cr(H_2O)_5Cl]Cl_2.H_2O$, $[Cr(H_2O)_4Cl_2]Cl.2H_2O$ and the value of coordination number (CN) of central metal ion in all these compounds, respectively is: *(2023-Manipur)*
    a. Geometrical isomerism, CN = 2
    b. Option isomerism, CN = 4
    c. Ionisation isomerism, CN = 4
    d. Solvate isomerism, CN = 6

14. Match List - I with List - II : [MR*] *(2022 Re)*

	List-I (Complexes)		List-II (Types)
A.	$[Co(NH_3)_5NO_2]Cl_2$ and $[Co(NH_3)_5ONO]Cl_2$	I.	ionization isomerism
B.	$[Cr(NH_3)_6][Co(CN)_6]$ and $[Cr(CN)_6][Co(NH_3)_6]$	II.	coordination isomerism
C.	$[Co(NH_3)_5(SO_4)]Br$ and $[Co(NH_3)_5Br]SO_4$	III.	linkage isomerism
D.	$[Cr(H_2O)_6]Cl_3$ and $[Cr(H_2O)_5Cl]Cl_2 \cdot H_2O$	IV.	solvate isomerism

Choose the **correct answer** from the options given below:

a. A-IV, B-III, C-II, D-I
b. A-III, B-I, C-II, D-IV
c. A-II, B-III, C-IV, D-I
d. A-III, B-II, C-I, D-IV

15. The IUPAC name of the complex- $[Ag(H_2O)_2][Ag(CN)_2]$ is: [MR*] *(2022)*

a. diaquasilver(I) dicyanidoargentate(I)
b. dicyanidosilver(II) diaquaargentate(II)
c. diaquasilver(II) dicyanidoargentate(II)
d. dicyanidosilver(I) diaquaargentate(I)

16. The type of isomerism shown by the complex $[CoCl_2(en)_2]$ is: *(2018)*

a. Geometrical isomerism
b. Coordination isomerism
c. Linkage isomerism
d. Ionization isomerism

17. The name of complex ion, $[Fe(CN)_6]^{3-}$ is: *(2015 Re)*

a. Hexacyanidoferrate (III) ion
b. Hexacyanoiron (III) ion
c. Hexacyanoferrate (III) ion
d. Tricyanoferrate (III) ion

18. Number of possible isomers for the complex $[Co(en)_2Cl_2]Cl$ will be: (en = ethylenediamine) [MR*] *(2015 Re)*

a. 4
b. 2
c. 1
d. 3

19. The complexes $[Co(NH_3)_6]$, $[Cr(CN)_6]$ and $[Cr(NH_3)_6]$, $[Co(CN)_6]$ are the examples of which type of isomerism? *(2011 Pre)*

a. Geometrical isomerism
b. Linkage isomerism
c. Ionization isomerism
d. Coordination isomerism

20. The complex, $[Pt(Py)(NH_3)BrCl]$ will have how many geometrical isomers? [MR*] *(2011 Pre)*

a. 2
b. 3
c. 4
d. 0

21. Which one of the following complexes is not expected to exhibit isomerism? *(2010 Mains)*

a. $[Ni(NH_3)_4(H_2O)_2]^{2+}$
b. $[Pt(NH_3)_2Cl_2]$
c. $[Ni(NH_3)_2Cl_2]$
d. $[Ni(en)_3]^{2+}$

22. The existence of two different coloured complexes with the composition of $[Co(NH_3)_4Cl_2]^+$ is due to: *(2010 Pre)*

a. Ionization isomerism
b. Linkage isomerism
c. Geometrical isomerism
d. Coodination isomerism

23. Which of the following does not show optical isomerism? [MR*] *(2009)*

a. $[Co(NH_3)_3Cl_3]^0$
b. $[Co(en)Cl_2(NH_3)_2]^+$
c. $[Co(en)_3]^{3+}$
d. $[Co(en)_2Cl_2]^+$

(en = ethylenediamine)

24. $[Co(NH_3)_4(NO_2)_2]Cl$ exhibits: *(2006)*

a. Linkage isomerism, ionization isomerism and optical isomerism
b. Linkage isomerism, ionization isomerism and geometrical isomerism
c. Ionization isomerism, geometrical isomerism and optical isomerism
d. Linkage isomerism, geometrical isomerism and optical isomerism

25. Which one of the following is expected to exhibit optical isomerism? (en = ethylenediamine) *(2005)*

a. cis-$[Pt(NH_3)_2Cl_2]$
b. trans-$[Co(en)_2Cl_2]$
c. trans-$[Pt(NH_3)_2Cl_2]$
d. cis-$[Co(en)_2Cl_2]$

26. Which of the following coordination compounds would exhibit optical isomerism? *(2004)*

a. Diamminedichloroplatinum (II)
b. Trans-dicyanobis (ethylenediamine) chromium (III) chloride
c. Tris-(ethylenediamine)cobalt (III) bromide
d. Pentaamminenitrocobalt (III) iodide

27. Which one of the following octahedral complexes will not show geometric isomerism? (A and B are monodentate ligands)? *(2003)*

a. $[MA_2B_4]$
b. $[MA_3B_3]$
c. $[MA_4B_2]$
d. $[MA_5B]$

28. The hypothetical complex chloro diaquatriammine cobalt (III) chloride can be represented as: [MR*] *(2002)*

a. $[CoCl(NH_3)_3(H_2O)_2]Cl_2$
b. $[Co(NH_3)_3(H_2O)Cl_3]$
c. $[Co(NH_2)_3(H_2O)_2Cl]$
d. $[Co(NH_3)_3(H_2O)_3]Cl_2$

29. Which of the following will give maximum number of isomers? *(2001)*

a. $[CO(NH_3)_4Cl_2]$
b. $Ni(en)(NH_3)_4]^{+2}$
c. $[Ni(C_2O_4)(en)_2]^{-2}$
d. $[Cr(SCN)_2(NH_3)_4]^+$

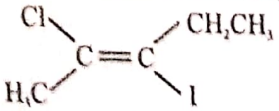
30. Which of the following will exhibit maximum ionic conductivity? [MR*] *(2001)*

a. $K_4[Fe(CN)_6]$
b. $[Co(NH_3)_6]Cl_3$
c. $[Cu(NH_3)_4]Cl_2$
d. $[Ni(CO)_4]$

31. Which complex compound will give four isomers? *(2000)*

a. $[Fe(en)_3]Cl_3$
b. $[Co(en)_2Cl_2]Cl$
c. $[Fe(PPh_3)_3NH_3ClBr]Cl$
d. $[Co(PPh_3)_3Cl]Cl_3$

32. IUPAC name of the compound: *(1998)*



a. Trans-3 iodi - 4 chloro - 3-pentene
b. cis-2-chloro-3-iodo-2-pentene
c. trans-2-chloro-3-iodo-2-pentene
d. cis-3iodo-4 chloro-3-pentene

33. The total number of possible isomers for the complex compound $[Cu^{II}(NH_3)_4][Pt^{II}Cl_4]$ **[MR*]** *(1998)*
a. 3 b. 6
c. 5 d. 4

34. IUPAC name of $[Pt(NH_3)_3(Br)(NO_2)Cl]Cl$ is: *(1998)*
a. Triammine chlorobromonitro platinum (IV) chloride
b. Triammine bromonitrochloro platinum (IV) chloride
c. Triammine bromochloronitro platinum (IV) chloride
d. Triammine nitrochlorobromi platinum (IV) chloride

35. The formula of dichlorobis (urea) copper(II) is: **[MR*]** *(1997)*
a. $[Cu\{O=C(NH_2)_2\}Cl]Cl$
b. $[CuCl_2\{O=C(NH_2)_2\}_2]$
c. $[Cu\{O=C(NH_2)_2\}Cl_2$
d. $[CuCl_2\{O=C(NH_2)_2\}_2]$

36. The number of geometrical isomers of the complex $[Co(NO_2)_3(NH_3)_3]$ is: *(1997)*
a. 4 b. 0
c. 2 d. 3

37. The number of geometrical isomers for $[Pt(NH_3)_2Cl_2]$ is: *(1995)*
a. 3 b. 4
c. 1 d. 2

Bonding in Coordination Compounds

38. The order of energy absorbed which is responsible for the color of complexes *(2022)*
A. $[Ni(H_2O)_2(en)_2]^{2+}$
B. $[Ni(H_2O)_4(en)]^{2+}$ and
C. $[Ni(en)_3]^{2+}$
is
a. B > A > C b. A > B > C
c. C > B > A d. C > A > B

39. Match List-I with List-II. **[MR*]** *(2021)*

	List-I		List-II
(A)	$[Fe(CN)_6]^{3-}$	(i)	5.92 BM
(B)	$[Fe(H_2O)_6]^{3+}$	(ii)	0 BM
(C)	$[Fe(CN)_6]^{4-}$	(iii)	4.90 BM
(D)	$[Fe(H_2O)_6]^{2+}$	(iv)	1.73 BM

Choose the correct answer from the options given below.
a. A-ii B-iv C-iii D-i
b. A-i B-iii C-iv D-ii
c. A-iv B-i C-ii D-iii
d. A-iv B-ii C-i D-iii

40. Which of the following is the correct order of increasing field strength of ligands to form coordination compounds? *(2020)*
a. $SCN^- < F^- < CN^- < C_2O_4^{2-}$
b. $F^- < SCN^- < C_2O_4^{2-} < CN^-$
c. $CN^- < C_2O_4^{2-} < SCN^- < F^-$
d. $SCN^- < F^- < C_2O_4^{2-} < CN^-$

41. Match the coordination number and type of hybridisation with distribution of hybrid orbitals in space based on Valence bond theory. **[MR*]** *(2020-Covid)*

	Coordination number and type of hybridisation		Distribution of hybrid orbitals in space
(A)	4, sp^3	(i)	Trigonal bipyramidal
(B)	4, dsp^2	(ii)	Octahedral
(C)	5, sp^3d	(iii)	Tetrahedral
(D)	6, d^2sp^3	(iv)	Square planar

Select the correct option:
a. A-iii B-iv C-i D-ii
b. A-iv B-i C-ii D-iii
c. A-iii B-i C-iv D-ii
d. A-ii B-iii C-iv D-i

42. What is the correct electronic configuration of the central atom in $K_4[Fe(CN)_6]$ based on crystal field theory? *(2019)*
a. $t^4_{2g}e^2_g$ b. $t^6_{2g}e^0_g$
c. $e^3t^3_{2g}$ d. $e^4t^2_{2g}$

43. The geometry and magnetic behaviour of the complex $[Ni(CO)_4]$ are? *(2018)*
a. Square planar geometry and diamagnetic
b. Tetrahedral geometry and diamagnetic
c. Tetrahedral geometry and paramagnetic
d. Square planar geometry and paramagnetic

44. Correct increasing order for the wavelengths of absorption in the visible region for the complexes of Co^{3+} is: **[MR*]** *(2017-Delhi)*
a. $[Co(NH_3)_6]^{3+}$, $[Co(en)_3]^{3+}$, $[Co(H_2O)_6]^{3+}$
b. $[Co(en)_3]^{3+}$, $[Co(NH_3)_6]^{3+}$, $[Co(H_2O)_6]^{3+}$
c. $[Co(H_2O)_6]^{3+}$, $[Co(en)_3]^{3+}$, $[Co(NH_3)_6]^{3+}$
d. $[Co(H_2O)_6]^{3+}$, $[Co(NH_3)_6]^{3+}$, $[Co(en)_3]^{3+}$

45. Pick out the correct statement with respect to $[Mn(CN)_6]^{3-}$ *(2017-Delhi)*
a. It is dsp^2 hybridised and square planar
b. It is sp^3d^2 hybridised and octahedral
c. It is sp^3d^2 hybridised and tetrahedral
d. It is d^2sp^3 hybridised and octahedral

46. The correct increasing order of trans-effect of the following species is: [MR*] *(2016-II)*

a. $NH_3 > CN^- > Br^- > C_6H_5^-$

b. $CN^- > C_6H_5^- > Br^- > NH_3$

c. $Br^- > CN^- > NH_3 > C_6H_5^-$

d. $CN^- > Br^- > C_6H_5^- > NH_3$

47. Jahn-Teller effect is not observed in high spin complexes of: [OS] *(2016-II)*

a. d^7 b. d^8

c. d^4 d. d^9

48. The hybridisation involved in complex $[Ni(CN)_4]^{2-}$ is (Atomic Number Ni = 28) *(2015 Re)*

a. d^2sp^3 b. dsp^2

c. sp^3 d. d^2sp^2

49. Which of these statements about $[Co(CN)_6]^{3-}$ is true? *(2015)*

a. $[Co(CN)_6]^{3-}$ has four unpaired electrons and will be in a low-spin configuration

b. $[Co(CN)_6]^{3-}$ has four unpaired electrons and will be in a high-spin configuration

c. $[Co(CN)_6]^{3-}$ has no unpaired electrons and will be in a high-spin configuration

d. $[Co(CN)_6]^{3-}$ has no unpaired electrons and will be in a low-spin configuration

50. Among the following complexes the one which shows zero crystal field stabilization energy (CFSE) is: [MR*] *(2014)*

a. $[Fe(H_2O)_6]^{3+}$ b. $[Co(H_2O)_6]^{2+}$

c. $[Co(H_2O)_6]^{3+}$ d. $[Mn(H_2O)_6]^{3+}$

51. A magnetic moment of 1.73 BM will be shown by one among the following: *(2013)*

a. $[Cu(NH_3)_4]^{2+}$ b. $[Ni(CN)_4]^{2-}$

c. $TiCl_4$ d. $[CoCl_6]^{4-}$

52. Low spin complex of d^6 - cation in an octahedral field will have the following energy: *(2012 Mains)*

a. $\frac{-2}{5}\Delta_0 + P$ b. $\frac{-12}{5}\Delta_0 + P$

c. $-\frac{12}{5}\Delta_0 + 3P$ d. $\frac{-2}{5}\Delta_0 + 2P$

53. Which one of the following is an outer orbital complex and exhibits paramagnetic behaviour? [MR*] *(2012 Pre)*

a. $[Co(NH_3)_6]^{3+}$ b. $[Ni(NH_3)_6]^{2+}$

c. $[Zn(NH_3)_6]^{2+}$ d. $[Cr(NH_3)_6]^{3+}$

54. Red precipitate is obtained when ethanol solution of dimethylglyoxime is added to ammonical Ni (II). Which of the following statements is not true? [OS] *(2012 Mains)*

a. Red complex has a square planar geometry

b. Complex has symmetrical H-bonding

c. Red complex has a tetrahedral geometry

d. Dimethylglyoxime functions as bidentate ligand

dimethylglyoxime =

55. Of the following complex ions, which is diamagnetic in nature? *(2011 Pre)*

a. $[CoF_6]^{3-}$ b. $[NiCl_4]^{2-}$

c. $[Ni(CN)_4]^{2-}$ d. $[CuCl_4]^{2-}$

56. Which of the following complex compounds will exhibit highest paramagnetic behaviour? *(2011 Mains)*
(Atomic Number Ti = 22, Cr = 24, Co = 27, Zn = 30)

a. $[Co(NH_3)_6]^{3+}$ b. $[Zn(NH_3)_6]^{2+}$

c. $[Ti(NH_3)_6]^{3+}$ d. $[Cr(NH_3)_6]^{3+}$

57. The d-electron configurations of Cr^{2+}, Mn^{2+}, Fe^{2+} and Co^{2+} are d^4, d^5, d^6 and d^7 respectively. Which one of the following will exhibit minimum paramagnetic behaviour? *(2011 Pre, 2007)*
(Atomic Number Cr = 24, Mn = 25, Fe = 26, Co = 27)

a. $[Cr(H_2O)_6]^{2+}$ b. $[Mn(H_2O)_6]^{2+}$

c. $[Fe(H_2O)_6]^{2+}$ d. $[Co(H_2O)_6]^{2+}$

58. Crystal field stabilization energy for high spin d^4 octahedral complex is: *(2010 Pre)*

a. $-0.6\Delta_0$ b. $-1.8\Delta_0$

c. $-1.6\Delta_0 + P$ d. $-1.2\Delta_0$

59. Which of the following complex ion is not expected to absorb visible light? [MR*] *(2010 Pre)*

a. $[Ni(H_2O_6)]^{2+}$ b. $[Ni(CN)_4]^{2-}$

c. $[Cr(NH_3)_6]^{3+}$ d. $[Fe(H_2O)_6]^{2+}$

60. Which of the following complex ions is expected to absorb visible light? *(2009)*
(Atomic number Zn = 30, Sc = 21, Ti = 22, Cr = 24)

a. $[Ti\ (en)_2\ (NH_3)_2]^{4+}$ b. $[Cr\ (NH_3)_6]^{3+}$

c. $[Zn\ (NH_3)_6]^{2+}$ d. $[Sc\ (H_2O)_3\ (NH_3)_3]^{3+}$

61. Out of TiF_6^{2-}, CoF_6^{3-}, Cu_2Cl_2 and $NiCl_4^{2-}$ (Z of Ti = 22, Co = 27, Cu = 29, Ni = 28) the colourless species are: [MR*] *(2009,1995)*

a. Cu_2Cl_2 and $NiCl_4^{2-}$ b. TiF_6^{2-} and Cu_2Cl_2

c. CoF_6^{3-} and $NiCl_4^{2-}$ d. TiF_6^{2-} and CoF_6^{3-}

62. In which of the following coordination entities the magnitude of Δ_o (CFSE in octahedral field) will be maximum: (atomic number Co = 27)? *(2008)*

a. $[Co(C_2O_4)_3]^{3-}$ b. $[Co(H_2O)_6]^{3+}$

c. $[Co(NH_3)_6]^{3+}$ d. $[Co(CN)_6]^{3-}$

63. Which of the following complexes exhibits the highest paramagnetic behaviour? Where gly = glycine, en = ethylenediamine and bpy = bipyridyl moities. (Atomic number Ti = 22, V = 23, Fe = 26, Co = 27): [MR*] *(2008)*

a. $[Ti(NH_3)_6]^{3+}$ b. $[V(gly)_2(OH)_2(NH_3)_2]^+$

c. $[Fe(en)(bpy)(NH_3)_2]^{2+}$ d. $[Co(Ox)_2(OH)_2]^-$

64. $[Cr(H_2O)_6]Cl_3$ (atomic number of Cr = 24) has a magnetic moment of 3.83 BM, the correct distribution of 3d electrons in the chromium of the complex is: [MR*] *(2006)*

a. $3d^1_{x^2-y^2}, 3d^1_{z^2}, 3d^1_{xz}$ b. $3d^1_{xy}, 3d^1_{x^2-y^2}, 3d^1_{yz}$

c. $3d^1_{xy}, 3d^1_{yz}, 3d^1_{xz}$ d. $3d^1_{xy}, 3d^1_{yz}, 3d^1_{z^2}$

65. Copper sulphate dissolves in excess of KCN to give: *(2006)*

a. CuCN b. $[Cu(CN)_4]^{3-}$

c. $[Cu(CN)_4]^{2-}$ d. $Cu(CN)_2$

66. Which one of the following is an inner orbital complex as well as diamagnetic in behaviour?

(Atomic number: Zn = 30, Cr = 24, Co = 27, Ni = 28) *(2005)*

a. $[Zn(NH_3)_6]^{2+}$ b. $[Cr(NH_3)_6]^{3+}$

c. $[Co(NH_3)_6]^{3+}$ d. $[Ni(NH_3)_6]^{2+}$

67. In an octahedral structure, the pair of d orbitals involved in d^2sp^3 hybridisation is: *(2004)*

a. $d_{xz}, d_{x^2-y^2}$ b. d_{z^2}, d_{xz}

c. d_{xy}, d_{yz} d. $d_{x^2-y^2}, d_{z^2}$

68. CN^- is a strong field ligand. This is due to the fact that : *(2004)*

a. It is a pseudohalide

b. It can accept electrons from metal species

c. It forms high spin complexes with metal species

d. It carries negative charge

69. Considering H_2O as a weak field ligand, the number of unpaired electrons in $[Mn(H_2O)_6]^{2+}$ will be: (Atomic number of Mn = 25) *(2004)*

a. Five b. Two

c. Four d. Three

70. Among $[Ni(CO)_4]$, $[Ni(CN)_4]^{2-}$, $[NiCl_4]^{2-}$ species, the hybridisation states at the Ni atom are, respectively

(Atomic number of Ni = 28) *(2004)*

a. sp^3, dsp^2, sp^3 b. sp^3, sp^3, dsp^2

c. dsp^2, sp^3, sp^3 d. sp^3, dsp^2, dsp^2

71. The number of unpaired electrons in the complex ion $[CoF_6]^{3-}$ is: (Atomic number: Co = 27) *(2003)*

a. 2 b. 3

c. 4 d. Zero

72. Atomic number of Cr and Fe are respectively 24 and 26, which of the following is paramagnetic with the spin of electron? *(2002)*

a. $[Cr(CO)_6]$ b. $[Fe(CO)_5]$

c. $[Fe(CN)_6]^{-4}$ d. $[Cr(NH_3)_6]^{+3}$

73. Which statement is incorrect? [MR*] *(2001)*

a. $Ni(CO)_4$ - Tetrahedral, paramagnetic

b. $Ni(CN)_4^{-2}$ Square planar, diamagnetic

c. $Ni(CO)_4$ - Tetrahedral, diamagnetic

d. $(Ni(Cl)_4]^{-2}$ - Tetrahedral, paramagnetic

74. In quantitative analysis of second group in laboratory, H_2S gas is passed in acidic medium for ppt. When Cu^{+2} and Cd^{+2} react with KCN, then in which of the following condition, ppt will not be formed due to relative stability? *(2000)*

a. $K_2[Cu(CN)_4]$ - More stable

b. $K_2[Cd(CN)_4]$ - Less stable

c. $K_1[Cu(CN)_2]$ - Less stable

d. $K_3[Cd(CN)_3]$ - More stable

75. Mg is present in: *(2000)*

a. Chlorophyll b. Haemoglobin

c. Vitamin-D d. Vitamin-B

Bonding in Metal Carbonyls

76. Given below are two statements: one is labelled as **Assertion (A)** and the other is labelled as **Reason (R)**. [MR*] *(2022 Re)*

Assertion (A): The metal carbon bond in metal carbonyls possesses both σ and π character.

Reason (R): The ligand to metal bond is a π bond and metal to ligand bond is a σ bond.

In the Light of the above statements, choose the **most appropriate** answer from the options given below:

a. (A) is not correct but (R) is correct

b. Both (A) and (R) are correct and (R) is the correct explanation of (A)

c. Both (A) and (R) are correct but (R) is not the correct explanation of (A)

d. (A) is correct but (R) is not correct

77. Iron carbonyl, $Fe(CO)_5$ is *(2018)*

a. Tetranuclear b. Mononuclear

c. Dinuclear d. Trinuclear

78. Which of the following has longest C-O bond length? (Free C—O bond length in CO is 1.128Å) [MR*] *(2016 - I)*

a. $[Mn(CO)_6]^+$ b. $Ni(CO)_4$

c. $[Co(CO)_4]^-$ d. $[Fe(CO)_4]^{2-}$

79. Which of the following carbonyl's will have the strongest C – O bond? *(2011 Mains)*

a. $V(CO)_6^-$ b. $Fe(CO)_5$

c. $Mn(CO)_6^+$ d. $Cr(CO)_6$

80. Which of the following does not have a metal- carbon bond? [MR*] *(2004)*

a. C_2H_5MgBr b. $K[Pt(C_2H_4)Cl_3]$

c. $Ni(CO)_4$ d. $Al(OC_2H_5)_3$

81. Among the following, which is not the π-bonded organometallic compound? *(2003)*

a. $K[PtCl_3(\eta^2-C_2H_4)]$ b. $Fe(\eta^5-C_5H_5)_2$

c. $Cr(\eta^6-C_6H_6)_2$ d. $(CH_3)_4Sn$

82. Which of following organometallic compound is σ and π bonded? [MR*] *(2001)*

a. $[Fe(\eta^5-C_5H_5)_2]$ b. $K[PtCl_3(\eta^2-C_2H_4)]$

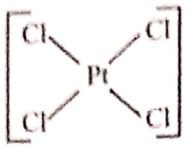
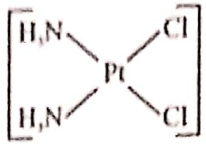
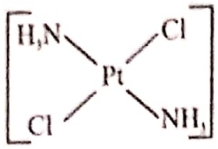
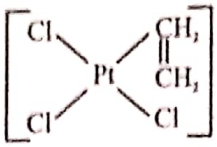
c. $[Co(CO)_5NH_3]^{+2}$ d. $Fe(CH_3)_3$

83. Shape of $Fe(CO)_5$ is: *(2000)*
a. Octahedral b. Square planar
c. Trigonal bipyramidal d. Square pyramidal

84. In metal carbonyl having general formula $M(CO)_x$ where M = metal, $x = 4$ and the metal is bonded to: *(1995)*
a. Carbon and oxygen b. C ≡ O
c. Oxygen d. Carbon

Applications of Coordination Compounds

85. Which of the following complexes is used to be as an anticancer agent? *(2014)*
a. cis-$[PtCl_2(NH_3)_2]$ b. cis-$K_2[PtCl_2Br_2]$
c. $Na_2[CoCl_4]$ d. mer–$[Co(NH_3)_3Cl_3]$

86. Which of the following is considered to be an anticancer species? *[MR*] (2004)*
a. 
b. 
c. 
d. 

87. In the silver plating of copper, $K[Ag(CN)_2]$ is used instead of $AgNO_3$. The reason is: *(2002)*
a. A thin layer of Ag is formed on Cu
b. More voltage is required
c. Ag^+ ions are completely removed from solution
d. Less availability of Ag^+ ions, as Cu can not displace Ag from $[Ag(CN)_2]^-$ ion

Answer Key

Team Kohinoor
TgT'd - @kohinoorofficial1

1. (b)	2. (d)	3. (c)	4. (d)	5. (d)	6. (d)	7. (d)			
11. (c)	12. (d)	13. (d)	14. (d)	15. (a)	16. (a)	17. (a)	18. (d)	19. (d)	20. (b)
21. (c)	22. (c)	23. (a)	24. (b)	25. (d)	26. (c)	27. (d)	28. (a)	29. (d)	30. (a)
31. (c)	32. (c)	33. (d)	34. (c)	35. (d)	36. (c)	37. (d)	38. (d)	39. (c)	40. (d)
41. (a)	42. (b)	43. (b)	44. (b)	45. (d)	46. (b)	47. (b)	48. (b)	49. (d)	50. (a)
51. (a)	52. (c)	53. (b)	54. (c)	55. (c)	56. (d)	57. (d)	58. (a)	59. (b)	60. (b)
61. (b)	62. (d)	63. (c)	64. (c)	65. (b)	66. (c)	67. (d)	68. (a)	69. (a)	70. (a)
71. (c)	72. (d)	73. (a)	74. (c)	75. (a)	76. (d)	77. (b)	78. (d)	79. (c)	80. (d)
81. (d)	82. (c)	83. (c)	84. (d)	85. (a)	86. (b)	87. (d)			

Explanations

1. **(b)** Homoleptic complexes have all ligands identical.

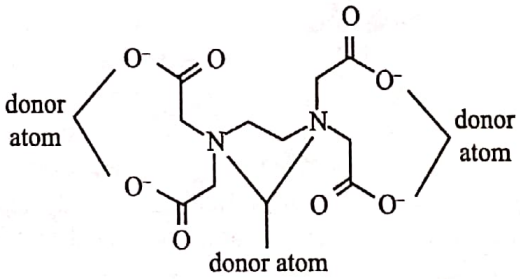
Potassium trioxalatoaluminate (III) is $K_3[Al(C_2O_4)_3]$ which has only oxalate ion as ligand.

All others have more than one type of ligands.

2. **(d) Ethylene diamine**, en is bidentate, chelating ligand. Chelating ligands increase stability due to higher entropy factor.

3. **(c)** $K_2[Pt(NH_3)_2Cl_2]$ is a complex salt and $KAl(SO_4)_2 \cdot 12H_2O$ (potash alum) is a double salt.

4. **(d)** A hexadentate ligand is one which can donate to central atom from its six donor sites. Ethylene diaminetetraacetate (EDTA) ion is hexadentate ligand with four "O" and two "N" donor atoms.



5. **(d)** $CoCl_3 \cdot 6NH_3 = [Co(NH_3)_6]Cl_3$

$CoCl_3 \cdot 5NH_3 = [Co(NH_3)_5Cl]Cl_2$

$CoCl_3 \cdot 4NH_3 = [Co(NH_3)_4Cl_2]Cl$

The reactions of the above complexes with excess $AgNO_3$ are:

$[Co(NH_3)_6]Cl_3 + 3AgNO_3 \rightarrow [Co(NH_3)_6](NO_3)_3 + 3AgCl\downarrow$

$[Co(NH_3)_5Cl]Cl_2 + 2AgNO_3 \rightarrow [Co(NH_3)_5Cl](NO_3)_2 + 2AgCl\downarrow$

$[Co(NH_3)_4Cl_2]Cl + AgNO_3 \rightarrow [Co(NH_3)_4Cl_2]NO_3 + AgCl\downarrow$

Hence, the correct order of the stoichiometrics of AgCl formed is 3, 2, 1.

6. **(d)** $CoCl_3 \cdot 3NH_3$ will not give test for chloride ions with silver nitrate at 25°C. This is because $CoCl_3 \cdot 3NH_3$ can also be written as $[CoCl_3(NH_3)_3]$, since all the chloride ions are present in the coordination sphere, hence they are firmly attached to the metal and do not ionize in solution. Therefore, they cannot form precipitate of AgCl with $AgNO_3$ solution.

7. **(d)** In the complex $[M(en)_2(C_2O_4)]Cl$, 'en' is a neutral ligand and $C_2O_4^{2-}$ and Cl are anionic ligands.

Let the oxidation number of M be x

$\Rightarrow x + 0 - 2 - 1 = 0$

$\Rightarrow \boxed{x = +3}$

Hence, Oxidation number of metal = 3

Coordination number is the number of atoms of the ligands that are directly bound to the central metal atom.

Hence, Coordination number of metal = 6 (en and $C_2O_4^{2-}$ are bidentate ligands)

Now, Sum of oxidation and coordination number = 3 + 6 = 9

8. **(b)** The cuprous cyanide dissolve in excess of KCN due to the formation of potassium cuprocyanide $K_3[Cu(CN)_4]$.

$2CuSO_4 + 4KCN \rightarrow 2CuCN + (CN)_2 + K_2SO_4$.

$CuCN + 3KCN \rightarrow K_3[Cu(CN)_4]$.

9. **(b)** $C_2O_4^{2-}$ is bidentate ligand.

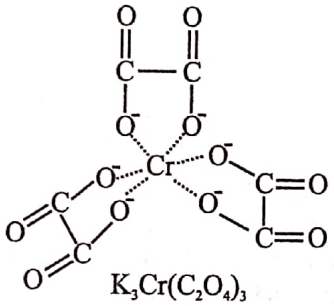
3 molecules attached from two sides with Ni makes coordination number 6.

10. **(c)** The only compound which represents the correct molecular formula as mentioned in question is $[Co(NH_3)_5NO_2]Cl_2$. The reactions takes place is:

$[Co(NH_3)_5NO_2]Cl_2 \rightarrow [Co(NH_3)_5NO_2]^{2+} + 2Cl^-$

$2Cl^- + 2AgNO_3 \rightarrow 2AgCl + 2NO_3$

11. **(c)**



$K_3Cr(C_2O_4)_3$

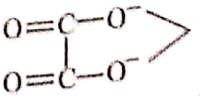
The number of atoms of the ligands that are directly bound to the central metal is known as coordination number. It is six here (see in figure).

Let oxidation state of Cr be *x*.

$\Rightarrow 3(+1) + x + 3(-2) = 0$

$\Rightarrow 3 + x - 6 = 0 \Rightarrow x = 3$

12. **(d)** A bidentate ligand is one which can donate to central metal ion from its two donor sites. Thus the only ligand, which is expected to be bidentate is $C_2O_4^{2-}$ as



Two donor sites.

13. **(d)** Given complex compounds exhibit solvate isomerism as it involves water molecules having co-ordination number = 6.

14. **(d)**

A. $[Co(NH_3)_5NO_2]Cl_2$ and $[Co(NH_3)_5ONO]Cl_2$ shows linkage isomerism due to the presence of ambidentate ligand NO_2.

B. $[Cr(NH_3)_6][Co(CN)_6]$ and $[Cr(CN)_6][Co(NH_3)_6]$ shows coordination isomerism due to exchange of ligands between coordination spheres.

C. $[Co(NH_3)_5(SO_4)]Br$ and $[Co(NH_3)_5Br]SO_4$ shows ionisation isomerism due to formation of different ions on ionization.

D. $[Cr(H_2O)_6]Cl_3$ and $[Cr(H_2O)_5Cl]Cl_2 \cdot H_2O$ shows solvate isomerism as number of water molecules present as ligands and as water of crystallization is different.

15. **(a)** While naming any Co-ordination compound, first ligand name comes followed by metal ion name with its oxidation state in Roman numerals enclosed in parentheses.

For the complex $[Ag(H_2O)_2][Ag(CN)_2]$, the cationic part is $[Ag(H_2O)_2]$ and exists as $[Ag(H_2O)_2]^{+1}$, thus, has Ag in +1 oxidation state.

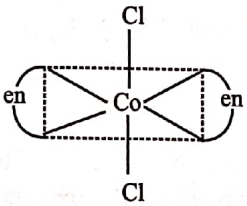
It's name will be diaquasilver(I).

The anionic part is $[Ag(CN)_2]$ which exists as $[Ag(CN)_2]^{-1}$. It also ahas Ag in +1 oxidation state. Also, whenever, there is negative charge on the complex, the metal ion name ends with "ate".

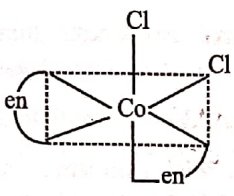
Hence, its name will be dicyanidoargentate(I).

Combining, we get the correct IUPAC name as diaquasilver (I) dicyanidoargentate (I).

16. **(a)** The type of isomerism shown by the complex $[CoCl_2(en)_2]$ is geometrical isomerism. This complex shows cis-trans isomerism. In the cis form, two 'Cl' ligands are adjacent to each other and two 'en' ligands are adjacent to each other. In the trans form, two 'Cl' ligands are opposite to each other and two 'en' ligands are opposites to each other.



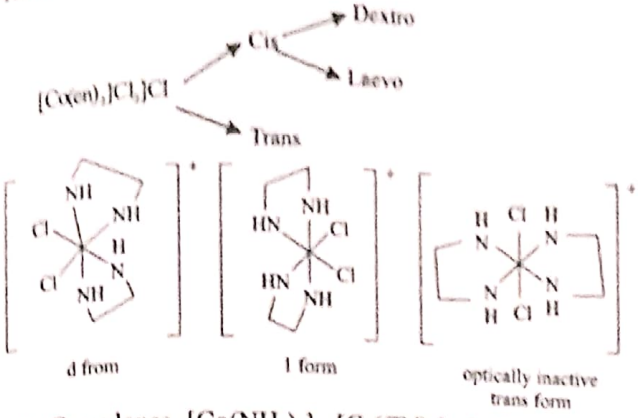
Trans-form
(optically inactive)



cis-form
(optically active)

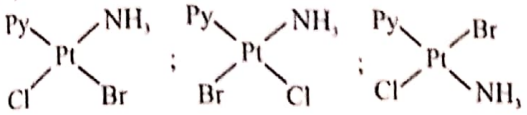
17. **(a)** While naming co-ordination compounds, ligands name come first, followed by metal ion name along with its oxidation state in parentheses. In $[Fe(CN)_6]^{3-}$, Fe is in +3 oxidation state. Also, when the complex ion is an anion, then the name of the metal ends with suffix 'ate'. Hence, the name of complex ion $[Fe(CN)_6]^{3-}$ is Hexacyanidoferrate (III) ion.

18. (d) Number of possible isomers for the complex $[Co(en)_2Cl_2]Cl$ will be 3. There are two geometrical isomers: *cis* and *trans*. The trans isomer is optically inactive whereas, the *cis* form exists in *d* and *l* forms.



19. (d) Complexes $[Co(NH_3)_6]$, $[Cr(CN)_6]$ & $[Co(CN)_6]$, $[Cr(NH_3)_6]$ are coordination isomers as they differ only in the ligand attached.

20. (b)



$[Pt(Py)(NH_3)(BrCl)]$ have 3 geometrical isomers.

21. (c) $[Ni(NH_3)_4(H_2O)_2]^{2+}$ shows solvate isomerism

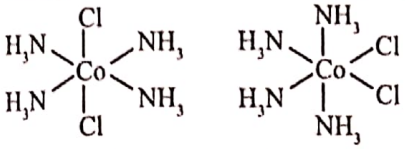
$[Pt(NH_3)_2Cl_2]$ shows cis – trans isomerism

$[Ni(NH_3)_2Cl_2]$ shows no isomerism as it has tetrahedral geometry

$[Ni(en)_3]^{2+}$ have 2 enantiomers (mirror images).

22. (c) The colour of coordinates complex is markedly influenced by the geometric arrangement of the ligand around metal center.

The geometrical isomers of $[Co(NH_3)_4Cl_2]^{\oplus}$ are:



Trans (Green) Cis (Violet)

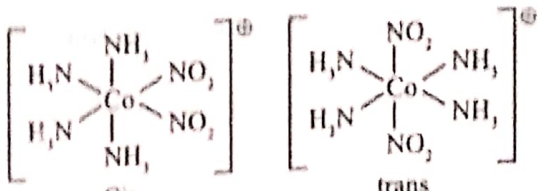
23. (a) $[MA_3B_3]$ → It shows geometrical isomerism known as facial - meridional isomerism, and does not show optical - isomerism.

Optical isomerism is shown by

1. $[M(AA)(x_2)(y_2)]$ → One symmetrical bidentate ligand.
2. $[M(AA)_3]$ → Containing three symmetrical bidentate ligand.

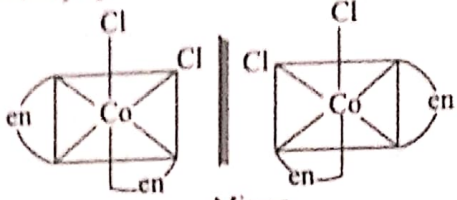
24. (b) $[Co(NH_3)_4(NO_2)_2]Cl$ has 2 linkage isomers, it also have an ionisation isomer and 2 geometrical isomers – facial and meridonial. Hence,

1. It's Linkage isomers are $[Co(NH_3)_4(NO_2)_2]Cl$ and $[Co(NH_3)_4(NO)_2]Cl$
2. Its ionisation isomers are $[Co(NH_3)_4(NO_2)Cl]NO_2$ and $[Co(NH_3)_4(NO_2)_2]Cl$
3. Its geometrical isomers are



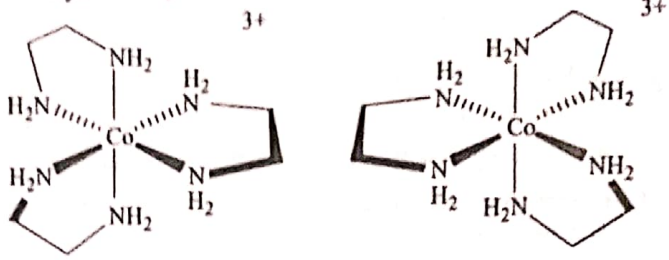
Cis trans

25. (d) Cis $[Co(en)_2Cl_2]$ exhibit optical isomerism.



Mirror

26. (c) Among all, only Tris-(ethylenediamine) cobalt(III) bromide is unsymmetric, and hence they show optical isomerism.



27. (d) For a compound to show geometric isomerism, it should be able to arrange in cis-trans configuration. Since in case of $[MA_5B]$, there are 5 same ligand, and one different ligand therefore, it is not possible to arrange them in cis-trans configuration.

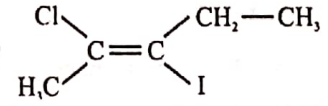
28. (a) Chlorodiaquatri-amminecobalt (III) chloride can be represented as $[CoCl(NH_3)_3(H_2O)_2]Cl_2$.

29. (d) $[Cr(SCN)_2(NH_3)_4]^+$ shows linkage, geometrical and optical isomerisms.

30. (a) Ionic conductivity depends upon the number of ions produced in aq. medium. $K_4[Fe(CN)_6]$ produces maximum no. of ions i.e. 5 : $4K^+ + [Fe(CN)_6]^{4-}$. Hence, it has maximum ionic conductivity.

31. (c) $[Fe(PPh_3)NH_3ClBr]Cl$ can give two optical and two geometrical isomers. While other complexes do not form geometrical isomers.

32. (c)



In these group preferential order is

$-Cl > -CH_3$ and $-I > -CH_2-CH_3$

Since, more preferential order containing group are attached in opposite side. So it is E (trans) isomers. Thus, its name is trans-2-chloro-3-iodo-2-pentene

33. (d) Total isomers of the given complex are four. These are -

(i) $[Cu(NH_3)_4][PtCl_4]$

(ii) $[Cu(NH_3)_3Cl][Pt(NH_3)Cl_3]$

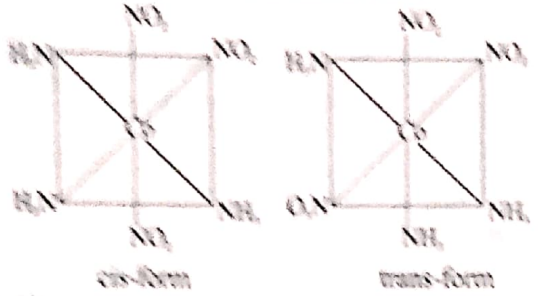
(iii) $[Pt(NH_3)_2Cl_2][Cu(NH_3)_2Cl_2]$

(iv) $[Pt(NH_3)_4][CuCl_4]$

34. (c) Oxidation number of central ion (Pt) = +4 and ligands are arranged in alphabetical order. So, triamminebromochloronitro platinum (IV) chloride.

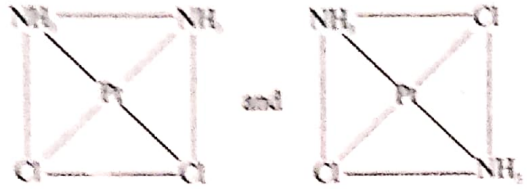
35. (d) According to nomenclature of coordination compounds, the correct name is $[Cu(C_2O_4)_2(O=C(NH_2)_2)_2]$

36. (c) Possible geometrical isomers are :



cis-form trans-form

37. (d)



cis-form trans-form

Hence, two geometrical isomers are given above.

38. (d) Energy absorbed is directly proportional to the crystal filed splitting, Δ_0.

Also, Δ_0 is directly proportional to Ligand strength.

According to the spectra chemical series, H_2O has weak field strength as compared to 'en'.

Thus, more the 'en' ligands in the complex, more will be the crystal field splitting, hence more energy will be absorbed.

Therefore, the correct order is C > A > B.

39. (c) (A) In $[Fe(CN)_6]^{3-}$, Fe is in +3 oxidation state.

Fe^{3+} – $[Ar]3d^5$

3d

In presence of strong ligand, pairing occurs

3d

n = 1, here 'n' represents no. of unpaired electrons.

The formula to calculate spin only magnetic moment (μ) is

$$\mu = \sqrt{n(n+2)} = \sqrt{3} = 1.73 \text{ BM}$$

(B) In $[Fe(H_2O)_6]^{3+}$, Fe is in + 3 oxidation state.

The electronic configuration of Fe^{3+} in presence of weak ligand, H_2O is

3d

Hence, n = 5

$$\mu = \sqrt{35} = 5.92 \text{ BM}$$

(C) $[Fe(CN)_6]^{4-}$ has Fe in + 2 oxidation state.

Fe^{2+} – $[Ar]3d^6$

$CN^{\ominus}$ is strong field ligand so, all electron are paired so n = 0

Hence, μ = 0.

(D) $[Fe(H_2O)_6]^{2+}$ has Fe in + 2 oxidation state.

Fe^{2+} : $[Ar]3d^6$

H_2O, here act as weak filed ligand, hence no pairing takes place. Hence n = 4.

Thus, $\mu = \sqrt{24} = 4.90$ BM

40. (d) Spectrochemical series is the correct order of increasing field strength of ligands to form coordination compounds.

$I^- < Br^- < S^{2-} < SCN^- < Cl^- < N_3^- < F^- < OH^- < C_2O_4^{2-} < H_2O < NCS^- < EDTA^{4-} < NH_3 < en < CN^- < CO$

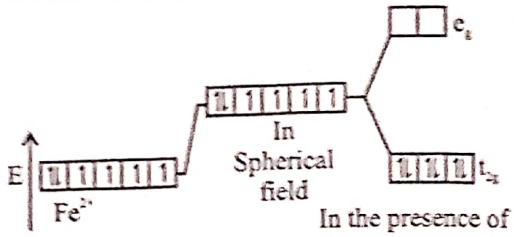
Thus, option d is correct.

41. (a)

Hybridisation	Geometry	Coordination number
sp^3	Tetrahedral	4
dsp^2	Square planar	4
sp^3d	Trigonal bipyramidal	5
d^2sp^3	Octahedral	6

42. (b) In $K_4[Fe(CN)_6]$, the electronic configuration of Fe in ground state : $[Ar]3d^64s^2$

The electronic configuration of Fe^{2+} : $[Ar]3d^6$



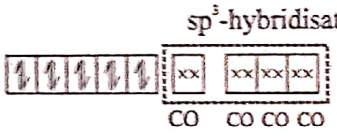
In the presence of 6 CN^- strong field, pairing of e^- takes place

Hence, the correct electronic configuration is $t_{2g}^6 e_g^0$.

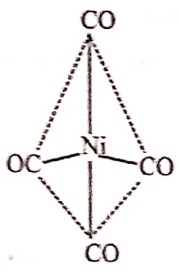
43. (b) Ni(28) : $[Ar]3d^8 4s^2$

∵ CO is a strong field ligand

Configuration would be :



For, four 'CO'-ligands, hybridisation would be sp^3 and thus the complex would be of tetrahedral geometry. Since, it contains zero unpaired electrons hence, diamagnetic also.



44. (b) According to the spectro chemical series, the fields strength of ligands are:

$I^- < Br^- < SCN^- < Cl^- < S^{2-} < F^- < OH^- < C_2O_4^{2-} < H_2O < NCS^- < EDTA^{4-} < NH_3 < en < CN^- < CO$.

Also, $\Delta E \propto$ field of ligand strength $\propto 1/\lambda$, that is, more is the field strength, less will be the wavelength. Hence, the correct order will be $[Co(en)_3]^{3+} < [Co(NH_3)_6]^{3+} < [Co(H_2O)_6]^{3+}$.

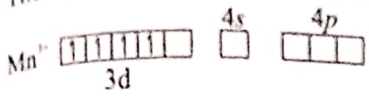
45. (d) In $[Mn(CN)_6]^{3-}$,

$x + 6(-1) = -3$

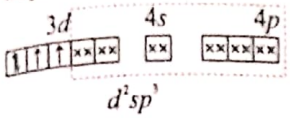
$x - 6 = -3$

$x = -3 + 6 \quad \Rightarrow \quad x = +3$

The electronic configuration of Mn^{3+} is $[Ar]\ 3d^4$.



In presence of CN^-, pairing occurs.

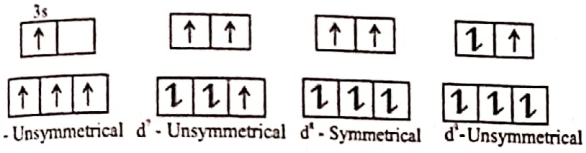


$\therefore d^2sp^3$ is required hybridisation.

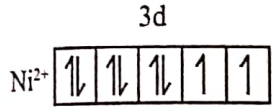
Hence, it is octahedral in shape.

46. (b) Trans effect can be defined as the effect of a ligand towards substitution on other ligand which is trans to it. The intensity of the trans-effect as measured by the increase in rate of substitution of the trans ligand. It follows the sequence : $CN^- > C_6H_5^- > Br^- > NH_3$.

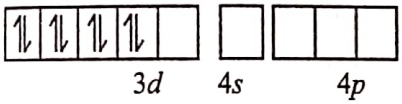
47. (b) Jahn - teller distortion is usually significant for asymmetrically occupied e_g orbital. The high spin complexes with d^{10}, d^8, d^5 and d^3 electrons do not exhibit Jahn-Teller distortions as they don't have any asymmetry.



48. (b) In $[Ni(CN)_4]^{2-}$, Ni is in +2 oxidation state. It's electronic configuration is $[Ar]3d^8$.



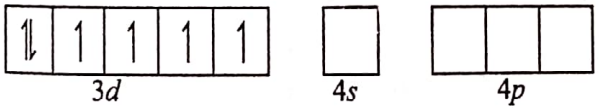
Since, $CN^{\ominus}$ is a SFL, hence pairing occurs.



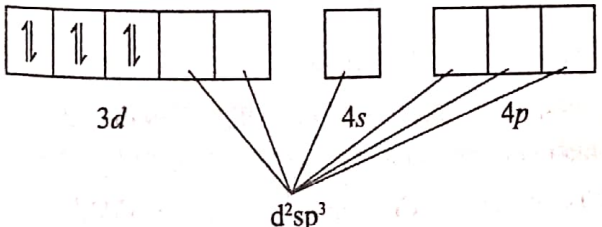
Hence it will form a low spin complex with dsp^2 hybridisation.

49. (d) In $[Co(CN)_6]^{3-}$, Co is in +3 oxidation state.

The electronic configuration of Co^{+3} is $[Ar]3d^6$.



Since, $CN^{\ominus}$ is a strong field ligand, hence, pairing occurs and low spin complex is formed.



Since, all electrons are paired, therefore, it is diamagnetic.

50. (a) In $[Fe(H_2O)_6]^{3+}$, Fe has oxidation state of +3. It 's electronic configuration is $[Ar]3d^5$.

A high spin complex is formed because H_2O is a weak field ligand.

C.F.S.E. $= (-0.4x + 0.6y)\Delta_0 + zP$

where x = number of electrons occupying t_{2g} orbital

y = number of electrons occupying e_g orbital

z = number of pairs of electrons.

For high spin, d^5 complex, electronic configuration is $t_{2g}^3\ eg^2$

$\Rightarrow x = 3$

$y = 3$

$z = 0$

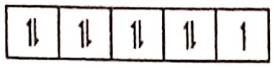
Hence, CFSE $= -0.4(3) + 0.6(2) + 0 = 0$

51. (a) Magnetic moment$(\mu) = \sqrt{n(n+2)}$

n = number of unpaired electron.

(a) In $(Cu(NH_3)_4]^{2+}$, ammonia is a neutral ligand, hence Cu exists as Cu^{2+}.

The electronic configuration of Cu^{2+} is $[Ar]3d^9$.



Hence, Cu^{2+} has 1 unpaired electron

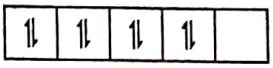
$\mu = \sqrt{n(n+2)}$

$= \sqrt{3} = 1.73BM$

(b) In $[Ni(CN)_4]^{2-}$, the oxidation state of Ni is +2.

The electronic configuration of Ni^{2+} is $[Ar]\ 3d^8$.

Since, $CN^{\ominus}$ is a strong field ligand, hence it will cause pairing.



Thus it has zero unpaired e^{-1}s.

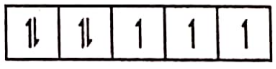
$\mu = \sqrt{0(0+2)} = 0$

(c) In $TiCl_4$, the oxidation state of Ti is +4. The electronic configuration of Ti^{+4} is [Ar].

Since, it has zero unpaired electrons, therefore,

$\mu = \sqrt{0(0+2)} = 0$

(d) In $[CoCl_6]^{4-}$, Co is in +2 oxidation state. The electronic configuration of Co^{+2} is $[Ar]3d^7$. Since, $Cl^{\ominus}$ is a weak field ligand, therefore, no pairing occurs.



Thus, n = 3

$\mu = \sqrt{3(3+2)} = \sqrt{15} = 3.87B.M$

52. (c) C.F.S.E. $= (-0.4x + 0.6y)\Delta_0 + zP$

where x = number of electrons occupying t_{2g} orbital

y = number of electrons occupying e_g orbital

z = number of pairs of electrons

For low spin d^5 complex, electronic configuration

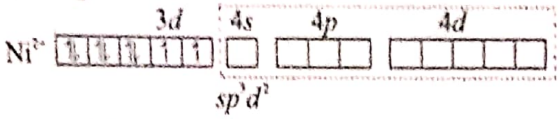
$= t_{2g}^{5} e_g^{0}$ or $t_{2g}^{2,2,2} e_g^{0}$

$\therefore x = 6, y = 0, z = 3$

C.F.S.E. $= (-0.4 \times 6 + 0 \times 0.6)\Delta_o + 3P$

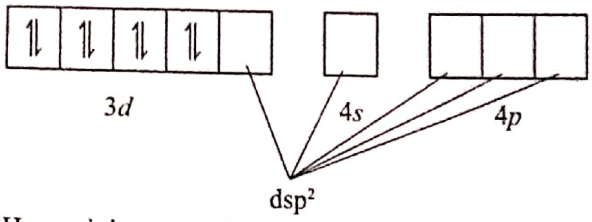
$= \frac{-12}{5}\Delta_o + 3P$

53. (b) In $[Ni(NH_3)_6]^{2+}$, Ni is in + 2 oxidation state with electronic configuration of $[Ar]3d^8$. Since, NH_3 act as W.F.L. therefore, no pairing occurs.



Hence, sp^3d^2 hybridised and an octahedral complex is formed which is paramagnetic in nature, due to presence of 2 upaired e^-s.

54. (c) In $[Ni(DMG)_2]$, Ni is in + 2 oxidation state. It's electronic configuration is $[Ar]3d^8$. $DMG^{\ominus}$ is a strong field ligand which causes pairing of electrons.



Hence, it is square planar.

55. (c) In $[Ni(CN)_4]^{2-}$, Ni is in zero oxidation state. It's electronic configuration is $[Ar]4s^23d^8$. Since $CN^{\ominus}$ is a strong filed ligand, therefore, CN^- causes pairing of unpaired electron in d-orbital. Thus leaving no unpaired electron & making the compound diamagnetic.

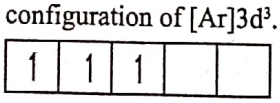
56. (d) More, the number of unpaired electrons, more will be the paramagnetic behaviour.

In $[Co(NH_3)_6]^{3+}$, Co is in +3 oxidation state with electronic configuration of $[Ar]3d^6$. NH_3 acts as a SFL, thus leaving zero unpaired electrons.

In $[Zn(NH_3)_6]^{2+}$, Zn is in +2 oxidation state with the electronic configuration of [Ar] $3d^{10}$. Hence, all electrons are paired, therefore, it has zero unpaired electrons.

In $[Ti(NH_3)_6]^{3+}$, Ti is in +3 oxidation state with electeronic configuration of $[Ar]3d^1$. Hence, one unpaired electron is present.

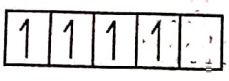
In $[Cr(NH_3)_6]^{3+}$, Cr is in +3 oxidation state with electronic configuration of $[Ar]3d^3$.



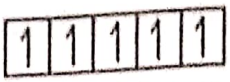
Since, it has 3 unpaired electrons, greater than all other given compounds, therefore, will exhibit more paramagnetic behaviour.

57. (d) Lesser the number of unpaired electrons, smaller will be the paramagnetic behaviour.

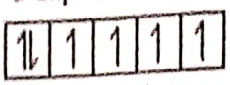
Cr^{2+}, Mn^{2+}, Fe^{2+} & Ni^{2+} contains

$Cr^{2+}(3d^4) =$ 

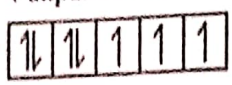
= 4 unpaired electron

$Mn^{2+}(3d^5) =$ 

= 5 unpaired electron

$Fe^{2+}(3d^6) =$ 

= 4 unpaired electron

$Co^{2+}(3d^7) =$ 

= 3 unpaired electron

As Co^{2+} has minimum number of unpaired electron thus th will show least paramagnetic behavior.

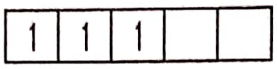
58. (a) When complexes are high spin, there is no pairing of e takes place.

For high spin d^4 octahedral complex, the electroni configuration is $t_{2g}^3 eg^1$.

Hence, CFSE = –0.4(no. of e^-s in t_{2g})Δ_0 + 0.6 (no. of e^-s i eg)Δ_0 = [–0.4(3) + 0.6(1)]Δ_0 = –0.6 Δ_0

59. (b) As $[Ni(CN)_4]^{2-}$ having a strong field ligand CN^-, whic will cause pairing of unpaired electron, hence, no unpaire electron will be left for absorbing light.

60. (b) In $[Cr(NH_3)_6]^{3+}$, Cr is in +3 oxidation state. It's electroni configuration is $[Ar]3d^3$.



3d

Since, it possesses three unpaired electrons, therefore paramagnetic in behaviour and hence, will absorb visibl light.

61. (b) In TiF_6^{2-}, Ti is in +4 oxidation state with electroni configuration of $[Ar]3d^0$. Thus, has no unpaired electron t absorb light so it is colourless compound.

Also, in Cu_2Cl_2, Cu is in +1 oxidation state with electroni configuration of $[Ar]3d^{10}$. Thus has no unpaired electrons and therefore, is a colorless compound.

62. (d) Among all 4 options in $[Co(CN)_6]^{3-}$, CN^- is a strong field ligand & it will have maximum Δ_0. So, it will cause pairing and forms low spin complex.

63. (c) Oxidation state of Ti in the complex $[Ti(NH_3)_6]^{3+}$ is +3.

$Ti^{3+} = 1s^22s^22p^63s^23p^63d^1$

Hence, no. of unpaired electron in d orbital is one.

Oxidation State of V in complex $[V(gly)_2(OH)_2(NH_3)_2]^+$

$= x + 2 \times 0 + 2 \times (-1) + 2 \times 0 = +1$

$\therefore x = +3$

$V^{3+} = 1s^22s^22p^63s^23p^63d^2$

Hence, no. of unpaired electron in d orbital is two.

Oxidation state of Fe in the given complex $[Fe(en)(bpy)(NH_3)_2]^{2+}$ is +2

$\therefore Fe^{2+} = 1s^22s^22p^63s^23p^63d^6$

Hence, no. of unpaired electron in d orbital is four.

Oxidation state of Co in the given complex $[Co(ox)_2(OH)_2]^{-1}$

$= x + 2 \times (-2) + 2 \times (-1) = -1$

$= x - 4 - 2 = -1$

$\therefore x = +5$

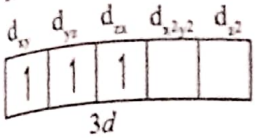
(not possible, common oxidation number of Co = +2, +3, +4)

$Co^{+5} = 1s^2 2s^2 2p^6 3s^2 3p^6 3d^4$

It should be an inner orbital complex (d^2sp^3 hybridisation) containing only one unpaired electron. So the complex having highest paramagnetism would be the complex of iron containing four unpaired electrons.

64. (c) In $[Cr(H_2O)_6]Cl_3$, Cr is in +3 oxidation state.

It's electronic configuration is $[Ar]3d^3$.



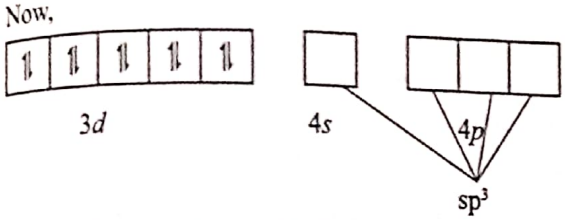
Hence, it's correct electronic configuration is $3d^1_{xy}, 3d^1_{yz}, 3d^1_{zx}$.

65. (b) Copper sulphate ($CuSO_4$) dissolves in KCN to form $[(CuCN)_4]^{3-}$.

66. (c) (a) In $[Zn(NH_3)_6]^{2+}$, Zn is in +2 oxidation state. It's electronic configuration is [Ar] $3d^{10}$.

Zn^{2+} has no unpaired electron in its *d*-orbital. It is diamagnetic.

Now,



Hence, it is not an inner orbital complex.

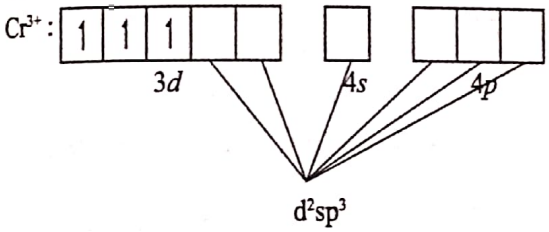
IUPAC name of the given co-ordination complex is given as-

$[Ag(H_2O)_2]\,[Ag(CN)_2]$

oxidation state of Ag = +1

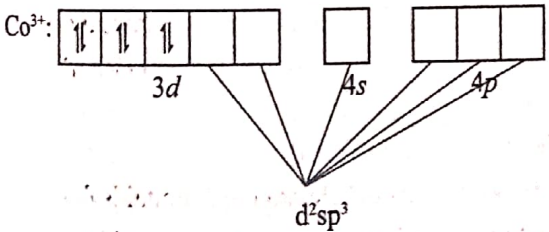
Therefore, the correct name of the compound is Diaquasilver(I) dicyanidoargentate(I)

(b) In $Cr[(NH_3)_6]^{3+}$, Cr is in + 3 oxidation sate.



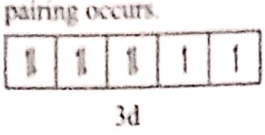
Since, it has unpaired electrons, therefore, paramagnetic. Also, in hybridisation as inner d-orbitals are involved, thus inner orbital complex.

(c) In $[Co(NH_3)_6]^{3+}$, Co is in +3 oxidation state. Also NH_3 acts as SFL with Co^{3+}, thus pairing occurs.



As, there is no unpaired electron and inner d-orbitals are used for hybridisation, hence paramagnetic and belongs to inner orbital complex.

(d) In $[Ni(NH_3)_6]^{2+}$, Ni is in +2 oxidation state. It's electronic configuration is $[Ar]3d^8$. NH_3 acts as a WFL, therefore, no pairing occurs.



Hence, paramagnetic in nature due to the presence of unpaired electrons.

67. (d) In an octahedral structure, the pair of d orbitals involved in d^2sp^3 hybridisation is $d_{x^2-y^2}, d_{z^2}$

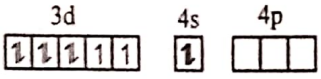
68. (a) $CN^{\ominus}$ is a strong field ligand because it is a pseudohalide ion. Pseudohalide ions are a stronger coordinating ligand and they have the ability to form sigma bond (from the pseudohalide to the metal) and π-bond (from the metal to pseudohalide).

69. (a) $Mn_{25} \rightarrow 3d^5 4s^2$

$Mn^{2+} \rightarrow 3d^5$ 1 1 1 1 1

In presence of weak field ligand, there will be no pairing of electrons. So it will form a high spin complex, i.e., the number of unpaired electron = 5

70. (a)



In $[Ni(CO)_4]$, Ni is in zero oxidation sate and since CO is a SFL.

$\therefore$ Pairing occurs = 1 1 1 1 1 (3d) × (4s) × × × (sp^3) (4p)

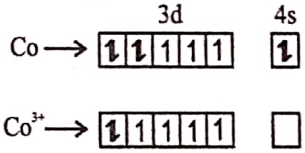
In $[Ni(CN)_4]^{2-}$, Ni is in +2 oxidation state and since $CN^{\ominus}$ is a SFL.

$\therefore$ pairing occurs = 1 1 1 1 × (3d) × (4s) × × (dsp^2) (4p)

In $[Ni(Cl)_4]^{2-}$, Ni is in +2 oxidation state, and $Cl^{\ominus}$ is WFL.

$\therefore$ No pairing occurs = 1 1 1 1 1 (3d) × (4s) × × × (sp^3) (4p)

71. (c) $[CoF_6]^{3-}$, Co is in + 3 oxidation sate



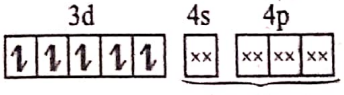
Thus, the number of unpaired electron = 4.

72. (d) $[Cr(NH_3)_6]^{+3}$, has Cr^{+3} cation. It's electronic configuration is $[Ar]3d^3$.

1 1 1

Hence, it has 1 unpaired electrons. Therefore, shows paramagnetic behaviour.

73. (a) In $Ni(CO)_4$ complex, Ni will have $3d^{10}$ configuration as Ni is in zero oxidation state.



Hence $[Ni(CO_4)]$ will have tetrahedral geometry. Since, all the e^-'s are paired, therefore, diamagnetic in nature.

74. (c) In $K_3[Cu(CN)_2]$, copper is in +1 oxidation state, while in $K_2[Cd(CN)_4]$, cadmium is in +2 oxidation state. The more the oxidation state of the central metal atom, the more is the stability of the complex.

75. (a) Chlorophyll is an organometallic complex in which the central atom is 'Mg' just like 'Fe' in haemoglobin. It's formula is found to be $C_{55}H_{72}MgO_5N_4$, which is the green colouring matter of leaves and green stem.

76. (d) In metal carbonyls, metal-carbon bond possesses both σ and π character. Therefore, the assertion is correct.

In metal carbonyls, the ligand to metal bond is σ bond and metal to ligand bond is π bond, therefore the reason is incorrect.

77. (b)

• Based on the number of metal atoms present in a complex, they are classified into mononuclear, dinuclear, trinuclear and so on.

Only $Fe(CO)_5$ is mononuclear, as it contains only one metal atom, that is, Fe.

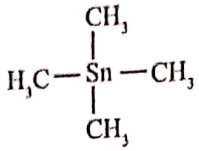
Hence, option (b) should be the right answer.

78. (d) As the negative charge on metal carbonyl complex increases back, pi bonding increases and therefore, the bond length of C-O bond increases, and hence, the bond length of metal-carbon bond decreases.

79. (c) As positive charge on the central metal atom increases, the metal shows lesser tendency to donate its electron density to the antibonding π-orbitals of CO ligand. This causes strengthening of the CO bond. Hence, $Mn(CO)^+_6$ has the strongest carbonyl bond.

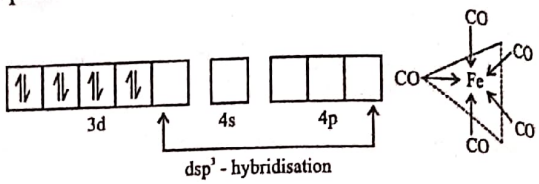
80. (d) $Al(OC_2H_5)_3$ contains bonding through oxygen & thus it does not have metal carbon bond.

81. (d) π-bonded organometallic compounds include organometallic compounds of alkenes, alkynes & some other carbon containing compounds that have electron in their p-orbital. $(CH_3)_4Sn$ is a sigma bonded organometallic compound as



82. (c) $[Co(CO)_5NH_3]^{2+}$. In this complex, Co - atom is attached with NH_3 through σ bonding and with CO through dative π-bond.

83. (c) In $Fe(CO)_5$, the 'Fe' atom is dsp^3 hybridised, therefore shape of the molecule is trigonal bipyramidal.



84. (d) In $M(CO)_4$ metal is bonded to the ligands via carbon atoms with both σ and π-bond character. Both metal to ligand and ligand to metal bonding are possible.

85. (a) Cis platin: Cis $[PtCl_2(NH_3)_2]$ is used as an anticancer agent.

86. (b) Cis-Platin is considered as an anticancer species. It's correct structure is shown in (b).

87. (d) Copper being more electropositive readily precipitates silver from their salt (Ag^+) solution.

$$Cu + 2AgNO_3 = Cu(NO_3)_2 + Ag$$

In $K[Ag(CN)_2]$ solution, a complex anion $[Ag(CN)_2]^-$ solution is formed, so Ag^+ are less available in the solution and hence, Cu cannot displace Ag from this complex ion.

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CHAPTER 7

Haloalkanes and Haloarenes

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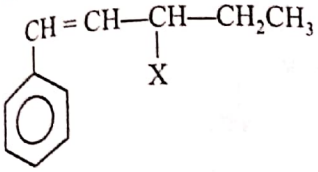
Classification of Organohalogen Compounds, Nature of C-X Bond

1. The given compound (2023)



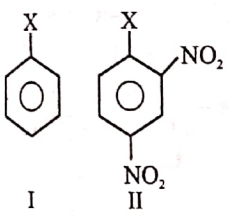
is an example of _____.

a. vinylic halide
b. benzylic halide
c. aryl halide
d. allylic halide

2. The correct sequence of bond enthalpy of 'C–X' bond is: [MR*] *(2021)*

a. $CH_3 - F > CH_3 - Cl > CH_3 - Br > CH_3 - I$
b. $CH_3 - F < CH_3 - Cl > CH_3 - Br > CH_3 - I$
c. $CH_3 - Cl > CH_3 - F > CH_3 - Br > CH_3 - I$
d. $CH_3 - F < CH_3 - Cl < CH_3 - Br < CH_3 - I$

3. The correct order of increasing reactivity of C-X bond towards nucleophile in the following compound is: *(2010 Pre)*



I II

$(CH_3)_3C - X$ III

$(CH_3)_2CH - X$ IV

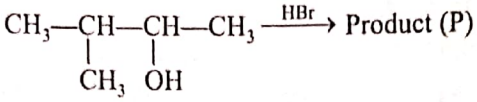
a. III < II < I < IV
b. I < II < IV < III
c. II < III < I < IV
d. IV < III < I < II

4. Reactivity order of halides for dehydrohalogenation is: *(2002)*

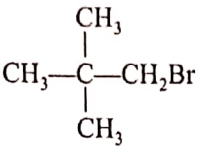
a. R – F > R – Cl > R – Br > R – I
b. R – I > R – Br > R – Cl > R – F
c. R – I > R – Cl > R – Br > R – F
d. R – F > R – I > R – Br > R – Cl

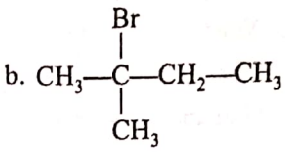
Haloalkanes and Chemical Reactions of Haloalkanes

5. Consider the following reaction and identify the product (P). [MR*] *(2023)*

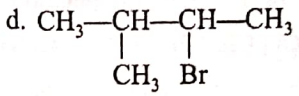


3–Methylbutan –2–ol

a. 

b. 

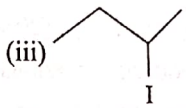
c. $CH_3CH = CH - CH_3$

d. 

6. The correct order for the rate of α, β-dehydrohalogenation for the following compounds is ..... . *(2023-Manipur)*

(i)

(ii)

(iii) 

a. (i) < (ii) < (iii)
b. (ii) < (i) < (iii)
c. (iii) < (ii) < (i)
d. (ii) < (iii) < (i)

7. Which amongst the following reactions of alkyl halides produces isonitrile as a major product ? [MR*] *(2023-Manipur)*

A. R–X + HCN →
B. R–X + AgCN →
C. R–X + KCN →
D. R–X + NaCH $\xrightarrow[C_2H_5OH]{H_2O}$

Choose the **most appropriate** answer from the options given below:

a. (D) only
b. (C) and (D) only
c. (B) only
d. (A) and (B) only

8. The major product formed in dehydrohalogenation reaction of 2-Bromo pentane is Pent-2-ene. This product formation is based on? *(2021)*

a. Hund's rule
b. Hofmann rule
c. Huckel's rule
d. Saytzeff's rule

9. Elimination reaction of 2-Bromo-pentane to form pent-2-ene is [MR*] *(2020)*

(1) β-Elimination reaction
(2) Follows Zaitsev rule
(3) Dehydrohalogenation reaction
(4) Dehydration reaction

a. (1), (3), (4)
b. (2), (3), (4)
c. (1), (2), (4)
d. (1), (2), (3)

10. An example of a sigma bonded organometallic compound is: *(2017-Delhi)*

a. Cobaltocene
b. Ruthenocene
c. Grignard's
d. Ferrocene

11. Consider the reaction

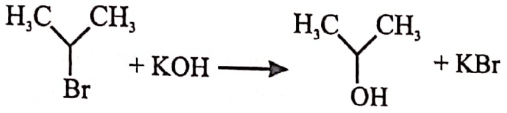
$CH_3CH_2CH_2Br + NaCN \rightarrow CH_3CH_2CH_2CN + NaBr$

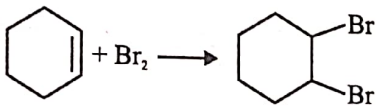
This reaction will be the fastest in: *(2016 - II)*

a. N,N'-dimethylformamide (DMF)
b. Water
c. Ethanol
d. Methanol

12. For the following reaction:

(A) $CH_3CH_2CH_2Br + KOH \rightarrow CH_3CH=CH_2 + KBr + H_2O$

(B) 

(C) 

Which of the following statements is correct? *(2016 - I)*

a. (A) is substitution, (B) and (C) are addition reactions.
b. (A) and (B) are elimination reactions and (C) is addition reaction.
c. (A) is elimination, (B) is substitution and (C) is addition reaction.
d. (A) is elimination, (B) and (C) are substitution reactions.

13. Which of the following reaction(s) can be used for the preparation of alkyl halides? [MR*] *(2015 Re)*

(I) $CH_3CH_2OH + HCl \xrightarrow{anh.ZnCl_2}$

(II) $CH_3CH_2OH + HCl \longrightarrow$

(III) $(CH_3)_3COH + HCl \longrightarrow$

(IV) $(CH_3)_2CHOH + HCl \xrightarrow{anh.\ ZnCl_2}$

a. (III) and (IV) only
b. (I), (III) and (IV) only
c. (I) and (II) only
d. (IV) only

14. In the following sequence of reactions $CH_3-Br \xrightarrow{KCN} A \xrightarrow{H_3O^+} B \xrightarrow{LiAlH_4} C$, the end product (C) is: *(2012 Prej)*

a. Ethyl alcohol
b. Acetone
c. Methane
d. Acetaldehyde

15. Consider the reactions:

(i) $(CH_3)_2CH-CH_2Br \xrightarrow{C_2H_5OH} (CH_3)_2CH-CH_2OC_2H_5 + HBr$

(ii) $(CH_3)_2CH-CH_2Br \xrightarrow{C_2H_5O^-} (CH_3)_2CH-CH_2OC_2H_5 + Br^-$

The mechanisms of reactions (i) and (ii) are respectively: *(2011 Mains)*

a. S_N2 and S_N2
b. S_N2 and S_N1
c. S_N1 and S_N2
d. S_N1 and S_N1

16. Which one is a nucleophilic substitution reaction among the following? *(2011 Prej)*

a. $CH_3CHO + HCN \rightarrow CH_3CH(OH)CN$

b. $CH_3-CH=CH_2 + H_2O \longrightarrow CH_3-\underset{OH}{CH}-CH_3$

c. $RCHO + R'MgX \longrightarrow R-\underset{OH}{CH}-R'$

d. $CH_3-CH_2-\underset{CH_3}{CH}-CH_2Br + NH_3 \longrightarrow CH_3-CH_2-\underset{CH_3}{CH}-CH_2NH_2$

17. Which of the following reactions is an example of nucleophilic substitution reaction? *(2009)*

a. $2RX + 2Na \rightarrow R-R + 2NaX$
b. $RX + H_2 \rightarrow RH + HX$
c. $RX + Mg \rightarrow RMgX$
d. $RX + KOH \rightarrow ROH + KX$

18. In a S_N2 substitution reaction of the type

$R-Br + Cl^- \xrightarrow{DMF} R-Cl + Br^-$

Which one of the following has the highest relative rate? *(2008)*

a. CH_3CH_2Br
b. $CH_3-CH_2-CH_2Br$
c. $CH_3-\underset{CH_3}{CH}-CH_2Br$
d. $CH_3-\underset{CH_3}{\overset{CH_3}{CH}}-CH_2Br$

19. Which of the following is least reactive in a nucleophilic substitution reaction? *(2004)*

a. $CH_2=CHCl$
b. CH_3CH_2Cl
c. $CH_2=CHCH_2Cl$
d. $(CH_3)_3C-Cl$

20. $CH_3CH_2Cl \xrightarrow{NaCN} X \xrightarrow{Ni/H_2} Y \xrightarrow{Acetic\ anhydride} Z$

Z in the above reaction sequence is: *(2002)*

a. $CH_3CH_2CH_2NHCOCH_3$
b. $CH_3CH_2CH_2NH_2$
c. $CH_3CH_2CH_2CONHCH_3$
d. $CH_3CH_2CH_2CONHCOCH_3$

21. An organic compound A (C_4H_9Cl) on reaction with Na/diethyl ether gives a hydrocarbon which on monochlorination gives only one chloro derivative then, A is: *(2001)*
a. t-butyl chloride
b. sec. butyl chloride
c. Iso butyl chloride
d. n-butyl chloride

22. The alkyl halide is converted into an alcohol by: *(1997)*
a. Elimination
b. Dehydrohalogenation
c. Addition
d. Substitution

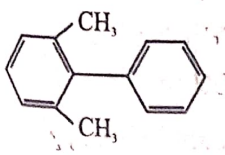
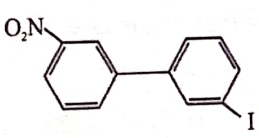
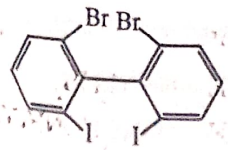
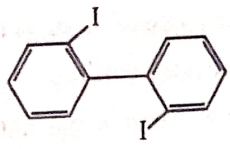
23. Grignard reagent is prepared by the reaction between: *(1994)*
a. Magnesium and alkane
b. Magnesium and aromatic hydrocarbon
c. Zinc and alkyl halide
d. Magnesium and alkyl halide

24. When chlorine is passed through propene at 400°C, which of the following is formed? *(1993)*
a. PVC
b. Allyl chloride
c. Propyl chloride
d. 1, 2-Dichloroethane

Stereochemical Aspects of Nucleophilic Substitution Reactions

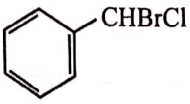
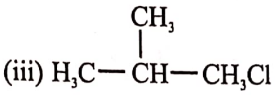
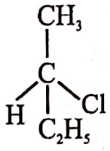
25. Predict the order of reactivity of the following four isomers towards S_N2 reaction. **[MR*]** *(2022 Re)*
(I) $CH_3CH_2CH_2CH_2Cl$
(II) $CH_3CH_2CH(Cl)CH_3$
(III) $(CH_3)_2CHCH_2Cl$
(IV) $(CH_3)_3CCl$
a. (IV) > (II) > (III) > (I)
b. (IV) > (III) > (II) > (I)
c. (I) > (II) > (III) > (IV)
d. (I) > (III) > (II) > (IV)

26. The **incorrect** statement regarding chirality is: **[MR*]** *(2022)*
a. A recemic mixture shows zero optical rotation.
b. S_N1 reaction yields 1 : 1 mixture of both enantiomers.
c. The product obtained by S_N2 reaction of haloalkane having chirality at the reactive site shows inversion of configuration.
d. Enantiomers are superimposable mirror images on each other.

27. Which of the following biphenyls is optically active? *(2016 - I)*
a. 
b. 
c. 
d. 

28. Two possible stereo-structures of $CH_3CHOHCOOH$, which are optically active, are called: *(2015 Re)*
a. Mesomers
b. Diastereomers
c. Atropisomers
d. Enantiomers

29. In a S_N1 reaction on chiral centres, there is: *(2015 Re)*
a. 100% inversion
b. 100% racemisation
c. Inversion more than retention leading to partial racemisation
d. 100% retention

30. Which of the following compounds will undergo racemisation when solution of KOH hydrolyses? *(2014)*
(i) 
(ii) $CH_3CH_2CH_2Cl$
(iii) 
(iv) 
a. (ii) and (iv)
b. (iii) and (iv)
c. (i) and (iv)
d. (i) and (ii)

31. Which of the following acids does not exhibit optical isomerism? *(2012 Pre)*
a. Tartaric acid
b. Maleic acid
c. α-amino acids
d. Lactic acid

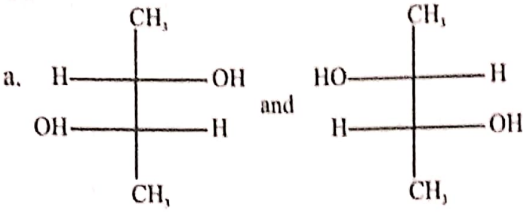
32. How many stereoisomers does the molecules have? $CH_3CH = CHCH_2CHBrCH_3$ *(2008)*
a. 2
b. 4
c. 6
d. 8

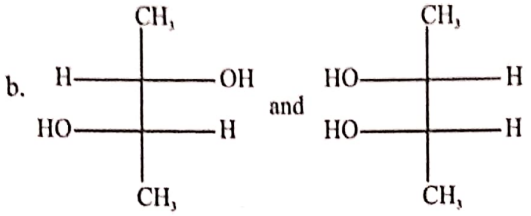
33. If there is no rotation of plane polarised light by a compound in a specific solvent, thought to be chiral, it may mean that: *(2007)*
a. The compound is certainly meso
b. There is no compound in the solvent
c. The compound may be a racemic mixture
d. The compound is certainly a chiral

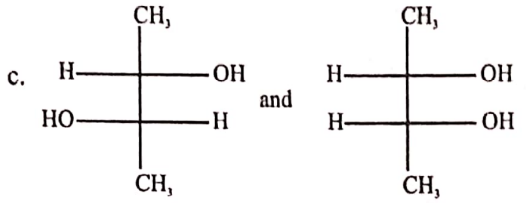
34. Which of the following is not chiral? *(2006)*
a. 2-butanol
b. 2, 3-dibromopentane
c. 3-bromopentane
d. 2-hydroxypropanoic acid

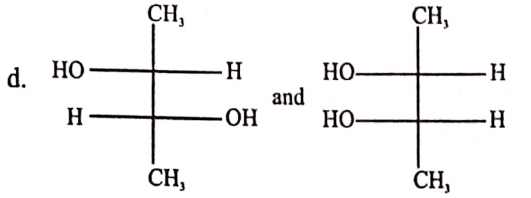
35. Which of the following undergoes nucleophilic substitution exclusively by S_N1 mechanism? *(2005)*
a. Benzyl chloride
b. Ethyl chloride
c. Chlorobenzene
d. Isopropyl chloride

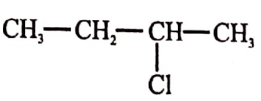
36. Which of the following pairs of compounds are enantiomers? [MR*] *(2003)*

a. 

b. 

c. 

d. 

37. 

obtained by chlorination of n-butane, will be: *(2001)*

a. Meso form
b. Racemic mixture
c. d-form
d. L-form

38. A compound of molecular formula is C_7H_{16} shows optical isomerism, compound will be: *(2001)*

a. 2, 3-dimethyl pentane
b. 2, 2-dimethyl butane
c. 2-methyl hexane
d. None of the above

39. R and S enantiomer differ in: *(2000)*

a. Rotation of PPL
b. Solubility in achiral solvent
c. Chemical properties
d. Dipole moment

40. In Friedel-Craft's alkylation, besides $AlCl_3$ the other reactants are: *(1999)*

a. $C_6H_6 + NH_2$
b. $C_6H_6 + CH_4$
c. $C_6H_6 + CH_3Cl$
d. $C_6H_6 + CH_3COCl$

41. Which of the following compounds is not chiral? *(1998)*

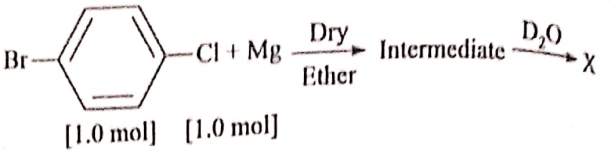
a. $DCH_2CH_2CH_2Cl$
b. CH_3CH_2CHDCl
c. CH_3CHDCH_2Cl
d. $CH_3CHClCH_2D$

42. Which of the following is an optically active compound? *(1989)*

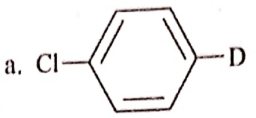
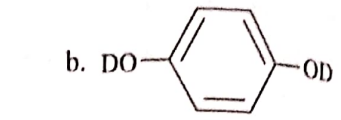
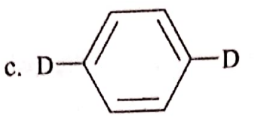
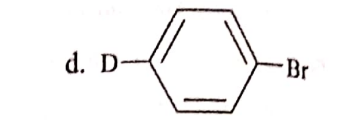
a. 1-Butanol
b. 1-Propanol
c. 2-Chlorobutane
d. 4-Hydroxyheptane

Haloarenes and Chemical Reactions of Haloarenes

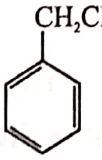
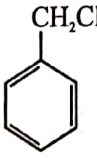
43. Identify 'X' in the following reaction. *(2023-Manipur)*



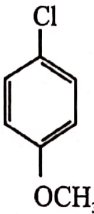
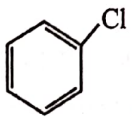
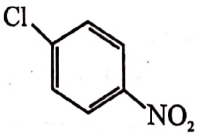
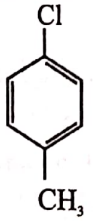
[1.0 mol] [1.0 mol]

a. 
b. 
c. 
d. 

44. Which of the following will NOT undergo S_N1 reaction with OH^-? [MR*] *(2020-Covid)*

a. $(CH_3)_3CCl$
b. 
c. 
d. $CH_2 = CH - CH_2Cl$

45. Which of the following compounds undergoes nucleophilic substitution reaction most easily? [MR*] *(2011 Mains)*

a. 
b. 
c. 
d. 

46. In the following reaction $C_6H_5CH_2Br \xrightarrow[2.H_3O^+]{1.Mg,\ Ether} X$ the product 'X' is: *(2010 Mains)*

a. $C_6H_5CH_2OCH_2C_6H_5$
b. $C_6H_5CH_2OH$
c. $C_6H_5CH_3$
d. $C_6H_5CH_2CH_2C_6H_5$

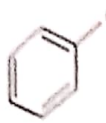
47. Which one is most reactive towards S_N1 reaction? *(2010 Pre)*

a. $C_6H_5CH_2Br$
b. $C_6H_5CH(C_6H_5)Br$
c. $C_6H_5CH(CH_3)Br$
d. $C_6H_5C(CH_3)(C_6H_5)Br$

48. Which one of these, is not compatible with arenes? *(1998)*

a. Greater stability
b. Delocalisation of π-electrons
c. Electrophilic additions
d. Resonance

49. Which one of the following compounds will be most easily attached by an electrophile? *(1998)*

a.
b.
c. 
d.

50. Replacement of Cl of chlorobenzene to give phenol requires drastic conditions. But chlorine of 2,4-dinitrochlorobenzene is readily replaced: [MR*] *(1997)*

a. NO_2 donates electron *meta* position
b. NO_2 withdraws electron from *ortho* and *para* positions
c. NO_2 make ring electron rich at *ortho* and *para*.
d. NO_2 withdraws electron from *meta* position.

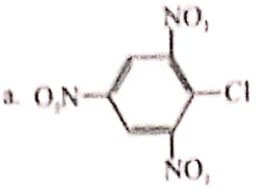
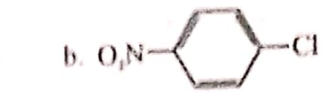
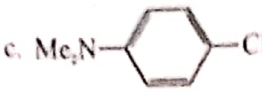
51. Chlorobenzene reacts with Mg in dry ether to give a compound which further reacts with ethanol to yield: *(1993)*

a. Phenol
b. Benzene
c. Ethyl benzene
d. Phenyl ether

52. Benzene reacts with *n*-propyl chloride in the presence of anhydrous $AlCl_3$ to give: *(1993)*

a. 3-propyl-1 -chlorobenzene
b. *n*-propyl benzene
c. No reaction
d. Isopropyl benzene

53. Which chloro derivative of benzene among the following would undergo hydrolysis most readily with aqueous sodium hydroxide to furnish the corresponding hydroxy derivative? *(1989)*

a. 
b. 
c. 
d. C_6H_5Cl

Polyhalogen Compounds

54. Industrial preparation of chloroform employs acetone and: *(1993)*

a. Phosgene
b. Calcium hypochlorite
c. Chlorine gas
d. Sodium chloride

55. Phosgene is a common name for: *(1988)*

a. Phosphoryl chloride
b. Thionyl chloride
c. Carbon dioxide and phosphine
d. Carbonyl chloride.

Answer Key

1. (d)	2. (a)	3. (b)	4. (b)	5. (b)	6. (d)	7. (c)	8. (d)	9. (d)	10. (c)
11. (a)	12. (c)	13. (b)	14. (a)	15. (a)	16. (d)	17. (d)	18. (a)	19. (a)	20. (a)
21. (a)	22. (d)	23. (d)	24. (b)	25. (d)	26. (d)	27. (c)	28. (d)	29. (c)	30. (c)
31. (b)	32. (b)	33. (a)	34. (c)	35. (a)	36. (a)	37. (b)	38. (a)	39. (a)	40. (c)
41. (a)	42. (c)	43. (a)	44. (b)	45. (c)	46. (c)	47. (d)	48. (c)	49. (d)	50. (b)
51. (b)	52. (d)	53. (a)	54. (b)	55. (d)					

Explanations

Team Kohinoor
TgI'd - @kohinooraofficial1

1. **(d)** Allylic halide have halogen bonded to sp^3 carbon which is adjacent to >C = C<

2. **(a)** Bond length from C-F to C-I increases as we move from F to I (due to increase in size of halogen atoms). Hence, bond enthalpy decreases from CH_3–F to CH_3–I.

$$\text{Bond length} \propto \frac{1}{\text{Bond enthalpy}}$$

	CH_3-F	CH_3-Cl	CH_3-Br	CH_3-I
B.E (kJ/mol)	452	351	293	234

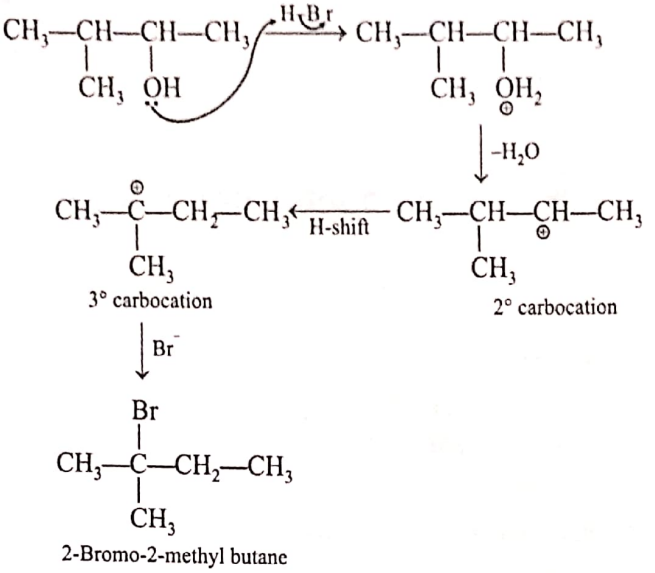
3. **(b)** I < II < IV < III

The order of reactivity is dependent on the stability of the intermediate carbocation formed by cleavage of C-X bond. The 3° carbocation (formed from III) will be more stable than its 2° counter part (formed from IV) which in turn will be more stable than the areniun ion (formed from I). Also, the aryl halide has a double bond character in the C-X bond which makes the cleavage more difficult. However, inspite of all the stated factors, II will be more reactive than I due to the presence of the electron withdrawing $-NO_2$ group. C-X bond becomes weak and undergoes nucleophilic substitution reaction.

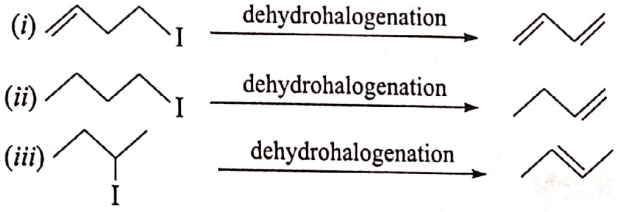
4. (b) During dehydrohalogenation C-I bond break more easily because I is a better leaving group than C-F bond. So relativity order of halide is

$R-I > R-Br > R-Cl > R-F$

5. (b) Initially, after protonation followed by loss of water, secondary carbocation is formed, further Hydride shift leads to 3° carbocation.



6. (d) The products of α, β-dehydrohalogenation are:



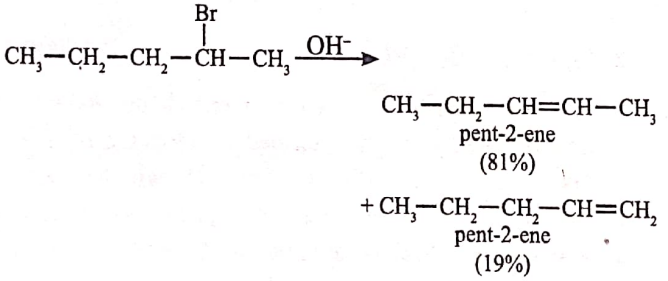
Rate of Dehydrahalogenation : (ii) < (iii) < (i).

7. (c) AgCN is covalent in nature and N is free to donate electron pairs which results in the formation of isonitrile as the major product.

(B) $R-X + Ag-C\equiv N \rightarrow R-NC$

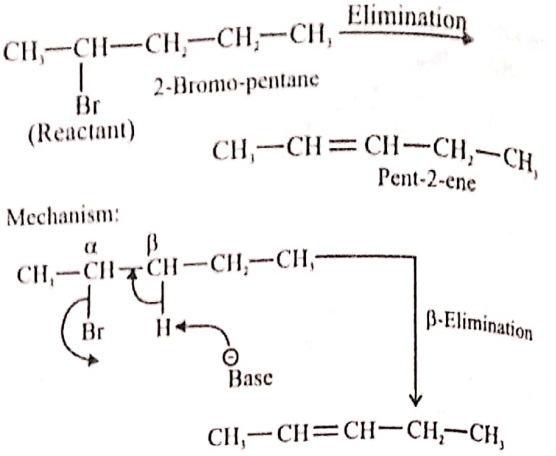
Isonitrile

8. (d) According to Saytzeff's rule in dehydrohalogenation reactions, alkene which contains the greater number of alkyl groups attached to the doubly bonded carbon atoms is the preferred product.



As, dehydrohologenation of 2-Bromo pentane follows thermodynamically more stable Product (i.e, more substituted alkene will be the major product). Hence, this is known as saytzeff's rule.

9. (d)



(1) The process is known as β–elimination as it involves elimination of β–Hydrogen.

(2) Pent-2-ene is major product known as Saytzeff's Product and it is more stable alkene. Since more substituted alkene is formed, it follows zaitsev's rule.

(3) Since 'H' and 'Br' are removed, it is dehydrohalogenation

Thus statements 1, 2 and 3 are correct.

So option d is correct

10. (c) Organometallic compounds have bond between carbon and metal.

$R-Br + Mg \xrightarrow{\text{dry ether}} R-MgBr$

Grignard reagent

∴ It is a single bond organometallic compound.

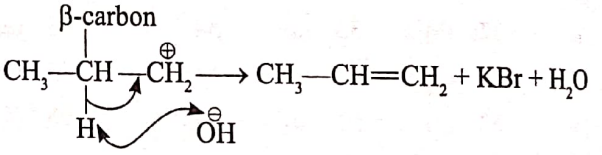
11. (a) $CH_3CH_2CH_2Br + NaCN \rightarrow CH_3CH_2CH_2CN + NaBr$

This is a substitution reaction & follows S_N2 pathway. Reagents which gives fastest S_N2 reaction are DMSO (dimethyl sulphoxide) or DMF (N,N'-dimethylformamide), these are non polar solvents. Because non-polar solvents stabilised transition state in S_N2 reaction.

12. (c) (A) **Step I:**

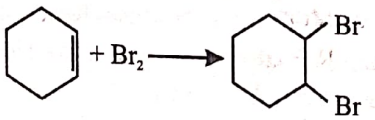
$CH_3-CH_2-CH_2-Br \xrightarrow{KOH} CH_3-CH_2-CH_2^{\oplus} + Br^- + KOH$

Step II:



In first step cleavage of C—Br bond slowly to form the carbocation intermediation and In IInd step base will remove hydrogen of β-carbon and double bond formation take place. Hence, Elimination will takes place.

(B) It is a substitution reaction because Br group is replaced/ substituted by –OH group

(C) 

This is an addition reaction as 2 Br groups are added, conversion of unsaturated compound to an saturated one.

13. (b) $CH_3CH_2OH + HCl \xrightarrow[ZnCl_2]{\text{anhy.}}$

$(CH_3)_3COH + HCl \rightarrow$

$(CH_3)_2CHOH + HCl \xrightarrow{ZnCl_2}$

The above 3 reaction will give alkyl halides, the reaction of primary & secondary alcohol requires the use of catalyst ($ZnCl_2$), but tertiary alcohol does not need any catalyst because the carbocation formed will be most stable.

$CH_3—CH_2—OH + HCl$ doesn't show reaction without in the presence of catalyst.

14. (a) $CH_3Br \xrightarrow{KCN} CH_3-CN \xrightarrow{H_3O^+} CH_3-COOH$

(A) (B) Ethanoic Acid

Methyl Bromide — Methyl Cyanide — $\downarrow LiAlH_4$ — $CH_3—CH_2OH$ Ethyl alcohol

15. (a)

(i) $(CH_3)_2CH-CH_2Br \xrightarrow{C_2H_5OH} (CH_3)_2CH-CH_2-OC_2H_5 + HBr$

(ii) $(CH_3)_2CH-CH_2Br \xrightarrow{C_2H_5O^-} (CH_3)_2CH-CH_2-O-C_2H_5 + Br^-$

Both the reactions follows S_N2 pathway as carbocation is not getting stabilized. As, both are primary carbocation.

16. (d) $CH_3—CH_2—\underset{\underset{CH_3}{|}}{CH}—CH_2—Br + NH_3 \longrightarrow$

1 – Bromo – 2 – Methyl butane

$CH_3—CH_2—\underset{\underset{CH_3}{|}}{CH}—HBr—\overset{+}{C}H_2—Br + NH_3$

$CH_3—CH_2—\underset{\underset{CH_3}{|}}{CH}—CH_2NH_2$

2 – Methyl butanamine

It is a nucleophilic substitution reaction.

17. (d) X^- (halogens) are good leaving group hence it is replaced or substituted by OH^- nucleophile.

18. (a) S_N2 reaction takes place when there is no steric hinderence present, in such cases the carbocation formed is least stable so, $CH_3–CH_2Br$ undergoes S_N2.

1° carbocartion readily undergoes S_N2 reaction.

19. (a) vinyl chloride ($CH_2 = CH — Cl$) is least reactive in nucleophilic substitution reaction as vinyl carbocation has least conjugation when formation of carbocation will takes place in S_N reaction. Here the +ve charge is in perpendicular orbitals of π-bond. Conjugation between π-bond and positive charge will not takes place. So, it is least reactive.

$CH_2=\overset{+}{C}H$

20. (a) $\underset{\text{ethyl chloride}}{CH_3CH_2Cl} \xrightarrow{NaCN} \underset{\text{ethyle cyanide}}{CH_3CH_2CN} \xrightarrow{Ni/H_2} \underset{\text{ethylanime}}{CH_3CH_2—NH_2}$

$\underset{(Y)}{CH_3CH_2CH_2NH_2} \xrightarrow[\text{anhydride}]{\text{acetic}} \underset{(Z)}{CH_3CH_2CH_2-NH-COCH_3}$

n–methyl propanamide

21. (a) Wurtz reaction → It involves the reaction of alkyl halides with Na in ethanol solution to form higher alkanes.

$2R-X + 2Na \rightarrow R-R + 2NaX$

In a given problem.

$2C_4H_9Cl + Na \xrightarrow{\text{ethanol}} C_4H_9.C_4H_9 + 2NaCl$

Compound A is t-butyl chloride. The product 2, 2, 3, 3-tetramethylbutane in this all CH_3 group having primary hydrogen only and able to give only one chloro derivatives.

$(CH_3)_3CC(CH_3)_3 \xrightarrow{Cl_2} CH_2Cl(CH_3)_2C-C(CH_3)_3$

22. (d) $C_2H_5Br + KOH \rightarrow C_2H_5OH + KBr$

Ethyl bromide (aqueous) Ethyl alcohol

This reaction is called as substitution reaction.

23. (d) Grignard reagent is prepared by heating an alkyl halide with dry magnesium powder in dry ether.

$R-X + Mg \xrightarrow{\text{Dry ether}} R-Mg-X$

Grignard reagent

24. (b) $CH_3CH=CH_2 \xrightarrow[-HCl]{Cl_2, 400°C} ClCH_2CH=CH_2$

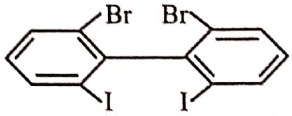
At 400°C temperature, allylic substitution occurs instead of addition.

25. (d) The order of reactivity of alkyl halides towards S_N2 reactions : $CH_3X > 1° > 2° > 3°$

Greater in steric hindrance, lesser will be the rate of S_N2 reaction. Hence, order of reactivity of S_N2 reaction is – (I) > (III) > (II) > (IV)

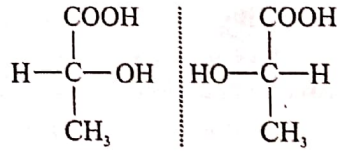
26. (d) Enantiomers are non-superimposable mirror images of each other. Therefore, statement (d) is incorrect, rest all the given statements are correct.

27. (c)



Ortho substituted biphenyls are optically active as both rings do not lie in the same plane these two biphenyl rings are perpendicular to each other & their mirror images are non-superimposable.

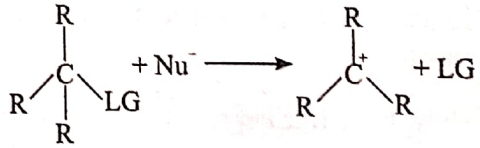
28. (d) Optically active pairs are called enantiomers.



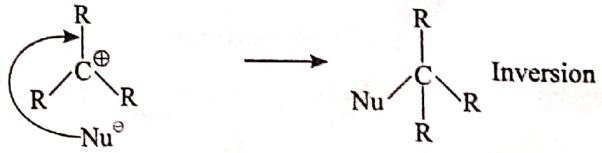
Enantiomers

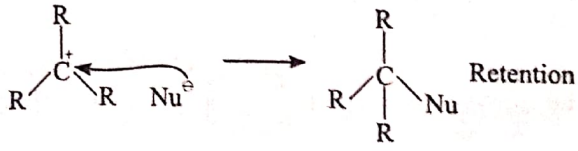
These compounds having chiral centre and have non-super imposable mirror image to each other.

29. (c) **Step 1:**



Step 2:



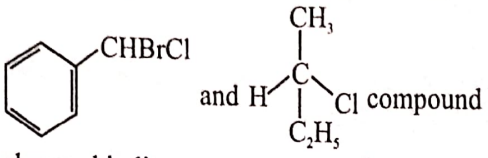


In case of S_N1 reaction formation of carbocation will take place at First step. After this, in second step Nu^- attack on the carbocation either from opposite to which the leaving group

departs or from the same side to which the leaving group departs. Because the geometry of carbocation is planar. If leaving group attack from the opposite side then, inversion of configuration will take place.

So, In S_N1 reaction racemisation will take place. But 100 %. racemisation will not take place. Nu^- always prefer back side attack due to less steric hindrance. So, inversion will be more than retention.

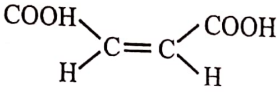
30. **(c)** Racemisation is shown by those compounds which show S_N1 reaction and have optical activity, out of the above 4 options only



shows chirality.

Both will form 2° carbocation which is more stable than other two 1° carbocation.

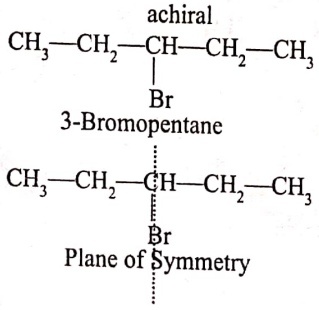
31. **(b)** Maleic acid does not have any chiral atom & does not exhibit any optical activity, it also have a plane of symmetry.

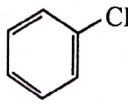


32. **(b)** Stereoisomers of $\overset{1}{C}H_3\overset{2}{C}H=\overset{3}{C}H\overset{4}{C}H_2\overset{5}{C}HBr\overset{6}{C}H_3$ are 1 cis & 1 trans at (2) carbon & 2 levo & dextro for optical activity at 5th C atom.

33. **(a)** Meso compound does not rotate plane polarised light. Compound which contains tetrahedral atoms with four different groups but the whole molecule is achiral is known as meso compound. It possesses a plane of symmetry and is optically inactive. One of the asymmetry carbon atom turns the plane polarised light to right and other to left and to same extent so that the rotation due to upper half is compensated by the lower half i.e. internally compensated and finally there is no rotation of plane polarised light.

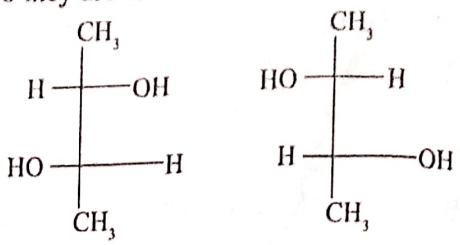
34. **(c)** 3–Bromopentane is an achiral compound as it have 2 similar groups attached to 1 C & also have a plane of symmetry.



35. **(a)** Benzyl chloride  undergoes nucleophilic substitution reaction.

As the carbocation formed during the first step is resonance stabilized with benzene ring.

36. **(a)** These are two non-superimposible mirror image of ea other, so they are enantiomers.

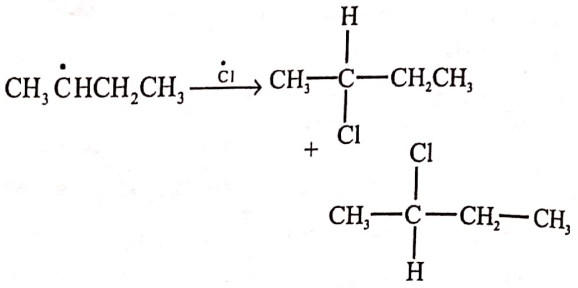


These compounds having chiral centre and have no superimposable mirror image to each other.

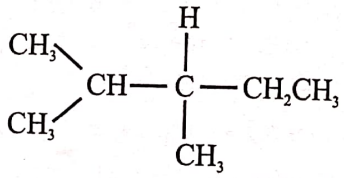
37. **(b)** Chlorination of n- butane takes place via free radica formation, i.e., $Cl_2 \rightarrow \dot{C}l + \dot{C}l$

$$CH_3CH_2CH_2CH_3 \xrightarrow{\dot{C}l} CH_3\dot{C}HCH_2CH_3 + HCl$$

sp^2-hybrid planar shape intermediate and $\dot{C}l$ may attack from either side to give.



38. **(a)** Organic compound exihibits the property of enantiomerism (optical isomerism) only when their molecules are chiral. Most chiral compounds have a chiral centre, which is an atom bonded to four different atoms or group



2, 3-dimethyl pentane has one chiral C-atom & do not have any symmetric element.

39. **(a)** 'R' & 'S' forms of an optically active compounds differ in their behaviour towards plane polarised light.

When PPL rotates towards right is called as 'R' form (rectus form) or d-form (dextro form) rotate plane polarised light towards left.

40. **(c)** Friedel - Craft's alkylation-

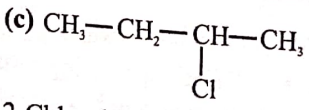
$$C_6H_6 + CH_3Cl \xrightarrow[AlCl_3]{Anhyd.} C_6H_5CH_3 + HCl$$

Toluene.

41. **(a)** Chiral carbon is that carbon whose all the four valancies are satisfied by four different group. Due to absence of asymmetric (chiral) C-atom

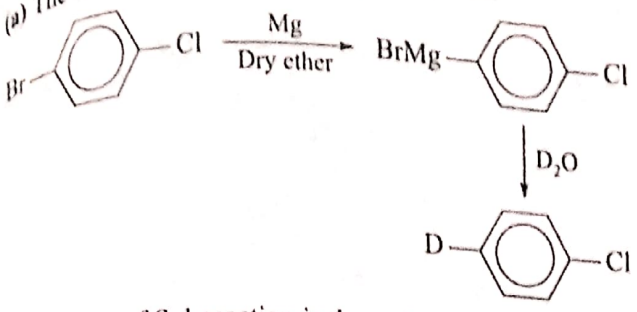
$D - CH_2 - CH_2 - CH_2Cl$

It is not a chiral molecules.

42. **(c)** 

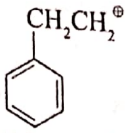
2-Chlorobutane contains a chiral carbon atom and hence is optically active compound.

43. (a) The formation of 'X' can be represented as:

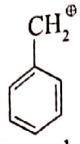


44. (b) The rate of S_N1 reaction is depends upon the stability of carbocation. Order of stability of carbocation is: $3^\circ > 2^\circ > 1^\circ$ Benzyl and allyl carbocation are more stable than 3° due to resonance. As the carbocation formed in S_N^1 reaction in following option.

(a) $(CH_3)_3C^{\oplus}$ 3°

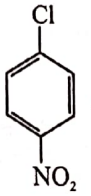
(b)  1° least stable

Hence it will not undergo S_N1 reaction.

(c)  Benzyl

(d) $CH_2=CH-\overset{\oplus}{C}H_2$ allyl

45. (c) For nucleophilic substitution, the attacking reagent must have negative charge at the target.

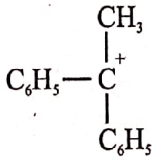


NO_2 is an electron withdrawing group and Halogen are also deactivating group due to – I effect.

46. (c) $\underset{\text{Benzyl promide}}{C_6H_5CH_2Br} \xrightarrow{Mg/ether}$

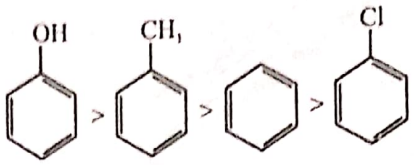
$C_6H_5CH_2MgBr \xrightarrow{Hydrolysis} \underset{\text{Toluene}}{C_6H_5CH_3} + Mg(Br)OH$

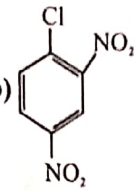
47. (d) S_N1 is usually favoured by those compounds which have the most stable carbocation, or where the carbocation formed is resonance or hyperconjugation stablised.



48. (c) Arenes undergoes electrophillic substitution reactions. Arenes do not give electrophillic addition reaction in normal state. Because if it undergoes in electro philic addition reaction, aromaticity of benzene ring will be disturbed.

49. (d) – Cl atom show o/p - directive influence but deactivated the benzene ring, while –OH and $-CH_3$ group show o/p. Influence but activated the benzene ring but in these –OH group activated the benzene ring more than $-CH_3$ due to +R effect of –OH group. Hence, order of electrophillic substitution is



50. (b) 

Withdrawal of electrons by $-NO_2$ groups from ortho/para positions cause easier removal of –Cl atom due to the development of positive charge on o and p-positions.

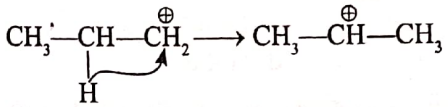
51. (b) $C_6H_5Cl \xrightarrow{Mg} C_6H_5MgCl \xrightarrow{CH_3CH_2OH} C_6H_6 + CH_3CH_2OMgCl$

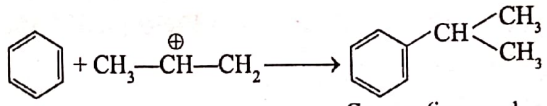
52. (d) $+ CH_3CH_2CH_2-Cl \xrightarrow[AlCl_3]{Anhy}$

Benzene at low temp n-propylchloride

$CH_3-CH_2-CH_2-Cl + AlCl_3 \longrightarrow AlCl_4^- + CH_3-CH_2-\overset{\oplus}{C}H_2$

at High temp. — rearrangement — rearrangement will takes place of carbocation — 1° carbocation





Cumene (isopropyl Benzene)

53. (a) Cl in 2, 4, 6-trinitrochlorobenzene is activated by three NO_2 groups at o and p-positions and hence undergoes hydrolysis most readily.

54. (b) $CaOCl_2 + H_2O \rightarrow Ca(OH)_2 + Cl_2$

Cl_2 so obtained acts as a mild oxidizing as well as chlorinating agent.

$CH_3-\underset{\underset{O}{\|}}{C}-CH_3 + CaOCl_2 \longrightarrow CHCl_3$

55. (d) Carbonyl chloride ($COCl_2$)

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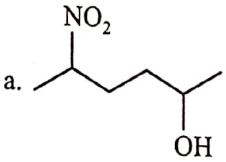
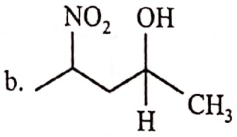
CHAPTER 8

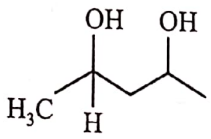
Alcohols, Phenols and Ethers

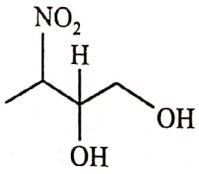
Alcohols

1. Which amongst the following will be most readily dehydrated under acidic conditions ? *(2023)*

a. 

b. 

c. 

d. 

2. $R–COOH \xrightarrow[(ii)H_2O/HCl]{(i)\text{“X”}} R–CH_2OH$

$R–CH=CH_2 \xrightarrow[(ii)H_2O,\ NaOH,\ H_2O_2]{(i)\text{“X”}} R–CH_2–CH_2–OH$

Identify 'X' in above reactions [MR*] *(2023-Manipur)*

a. B_2H_6 b. $LiAlH_4$

c. $NaBH_4$ d. H_2/Pd

3. Reagents which can be used to convert alcohols to carboxylic acids, are [MR*] *(2023-Manipur)*

A. $CrO_3–H_2SO_4$

B. $K_2Cr_2O_7 + H_2SO_4$

C. $KMnO_4 + KOH/H_3O^+$

D. Cu, 573 K

E. $CrO_3, (CH_3CO)_2O$

Choose the **most appropriate** answer form the options given below:

a. (B), (C) and (D) only b. (B), (D) and (E) only

c. (A), (B) and (C) only d. (A), (B) and (E) only

4. Given below are two statements: [MR*] *(2022)*

Statement-I: In Lucas test, primary, secondary and tertiary alcohols are distinguished on the basis of their reactivity with conc. $HCl + ZnCl_2$, known as Lucas Reagent.

Statement-II: Primary alcohols are most reactive and immediately produce turbidity at room temperature on reaction with Lucas Reagent.

In the light of the above statements, choose the **most appropriate** answer from the options given below:

a. Statement-I is incorrect but Statement-II is correct.

b. Both Statement-I and Statement-II are correct.

c. Both Statement-I and Statement-II are incorrect.

d. Statement-I is correct but Statement-II is incorrect.

5. What is the IUPAC name of the organic compound formed in the following chemical reaction? *(2021)*

$\text{Acetone} \xrightarrow[(ii)\ H_2O,\ H^+]{(i)\ C_2H_5MgBr,\ \text{dry ether}} \text{Product}$

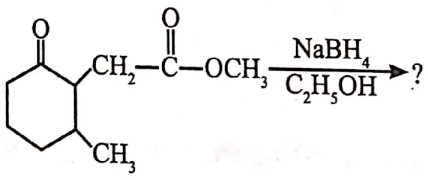
a. Pentan-2-ol

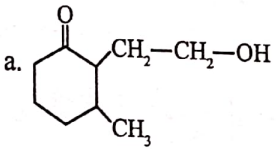
b. Pentan-3-ol

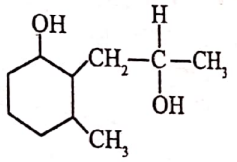
c. 2-methyl butan-2-ol

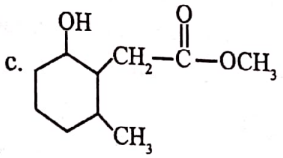
c. 2-methyl propan-2-ol

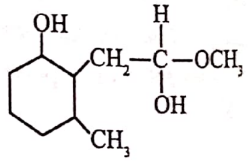
6. The product formed in the following chemical reaction is: *(2021)*



a. 

b. 

c. 

d. 

7. Reaction between acetone and methylmagnesium chloride followed by hydrolysis will give : *(2020*

a. Sec. butyl alcohol b. Tert. butyl alcohol

c. Isobutyl alcohol d. Isopropyl alcohol

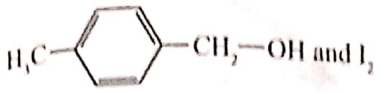
8. $CH_3CH_2CH=CH_2 \xrightarrow[H_2O,\ H_2O/OH]{B_2H_6} Z$

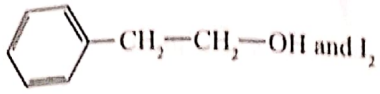
What is Z? *(2020-Covid*

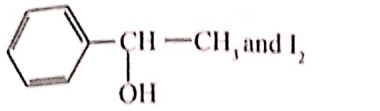
a. $CH_3CH_2\underset{\displaystyle OH}{\underset{|}{C}}HCH_3$ b. $CH_3CH_2CH_2CHO$

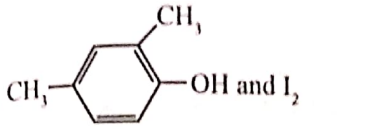
c. $CH_3CH_2CH_2CH_3$ d. $CH_3CH_2CH_2CH_2OH$

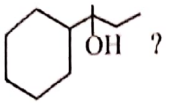
9. Compound A, $C_8H_{10}O$, is found to react with NaOI (produced by reacting Y with NaOH) and yields a yellow precipitate with characteristic smell. A and Y are respectively [MR*] *(2018)*

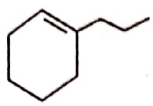
a. 

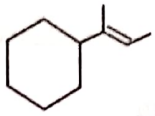
b. 

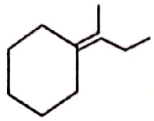
c. 

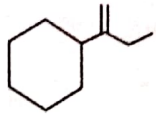
d. 

10. Which of the following is not the product of dehydration of  ? [MR*] *(2015 Re)*

a. 

b. 

c. 

d. 

11. When glycerol is treated with excess of HI, it produces: *(2010 Mains)*

a. 2-iodopropane
b. Allyl iodide
c. Propene
d. Glycerol triiodide

12. Consider the following reaction,

$$\text{ethanol} \xrightarrow{PBr_3} X \xrightarrow{\text{alc. KOH}} Y \xrightarrow[\text{(ii) } H_2O,\ \text{heat}]{\text{(i) } H_2SO_4,\ \text{room temperature}} Z;$$

the product Z is: [MR*] *(2009)*

a. $CH_3CH_2{-}O{-}CH_2{-}CH_3$
b. $CH_3{-}CH_2{-}O{-}SO_3H$
c. CH_3CH_2OH
d. $CH_2{=}CH_2$

13. The general molecular formula, which represents the homologous series of alkanols is: *(2006)*

a. $C_nH_{2n+2}O$
b. $C_nH_{2n}O_2$
c. $C_nH_{2n}O$
d. $C_nH_{2n+1}O$

14. Ethylene oxide when treated with Grignard reagent yields: *(2006)*

a. Primary alcohol
b. Secondary alcohol
c. Tertiary alcohol
d. Cyclopropyl alcohol

15. Which of the following will not form a yellow precipitate on heating with an alkaline solution of iodine? *(2004)*

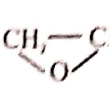
a. $CH_3CH_2CH(OH)CH_3$
b. CH_3OH
c. CH_3CH_2OH
d. $CH_3CH(OH)CH_3$

16. n-propyl alcohol and isopropyl alcohol can be chemically distinguished by which reagent: *(2002)*

a. PCl_5
b. Reduction
c. Oxidation with Potassium dichromate
d. Ozonolysis

17. Which of following is correct? *(200*

a. Any aldehyde gives secondary alcohol on reduction
b. Reaction of vegetable oil with H_2SO_4 give glycerin
c. C_2H_5OH, iodine with NaOH gives iodoform
d. Sucrose on reaction with NaCl give invert sugar

18. Reaction  with RMgX leads to formation o *(199*

a. RCHOHR
b. $RCHOHCH_3$
c. RCH_2CH_2OH
d.

19. When 3,3-dimethyl-2-butanol is heated with H_2SO_4, th major product obtained is: *(199*

a. 2,3-dimethyl-2-butene
b. *cis* and *trans* isomers of 2,3-dimethyl-2-butene
c. 2,3-dimethyl-1-butene
d. 3,3-dimethyl-1-butene

20. On heating glycerol with concentrated H_2SO_4, a compound i obtained which has bad odour. The compound is: *(1994*

a. Acrolein
b. Formic acid
c. Allyl alcohol
d. Glycerol sulphate

21. Ethanol and dimethyl ether form a pair of functional isomers The boiling point of ethanol is higher than that of dimethyl ether, due to the presence of: *(1993)*

a. H-bonding in ethanol
b. H-bonding in dimethyl ether
c. CH_3 group in ethanol
d. CH_3 group in dimethyl ether

22. Which one of the following on oxidation gives a ketone? *(1993)*

a. Primary alcohol
b. Secondary alcohol
c. Tertiary alcohol
d. All of these

23. What is formed when a primary alcohol undergoes catalyti dehydrogenation? *(1993*

a. Aldehyde
b. Ketone
c. Alkene
d. Acid

24. How many isomers of $C_5H_{11}OH$ will be primary alcohols *(199*

a. 5
b. 4
c. 2
d. 3

25. Methanol is industrially prepared by: *(199*

a. Oxidation of CH_4 by steam at 900°C
b. Reduction of HCHO using $LiAlH_4$
c. Reaction of HCHO with a solution of NaOH
d. Reduction of CO using H_2 and $ZnO{-}Cr_2O_3$.

26. HBr reacts fastest with: *(19*

a. 2-Methyl propan-1-ol
b. 2-Methyl propan-2-ol
c. propan-2-ol
d. propan-1-ol

27. The compound which reacts fastest with Lucas reagent at room temperature is: *(1989)*

a. butan-1-ol b. butan-2-ol
c. 2-methylpropan-1-ol d. 2-methylpropan-2-ol.

28. Propene, $CH_3CH = CH_2$ can be converted into 1-propanol by oxidation. Indicate which set of reagents amongst the following is ideal for the above conversion? *(1989)*

a. $KMnO_4$ (alkaline)
b. Osmium tetroxide (OsO_4/CH_2Cl_2)
c. B_2H_6 and alk. H_2O_2.
d. O_3/Zn.

29. Lucas reagent is: *(1988)*

a. Conc. HCl and anhydrous $ZnCl_2$
b. Conc. HNO_3 and hydrous $ZnCl_2$
c. Conc. HCl and hydrous $ZnCl_2$
d. Conc. HNO_3 and anhydrous $ZnCl_2$

Phenols

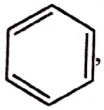
30. Match the reagents (List-I) with the product (List-II) obtained from phenol. **[MR*]** *(2022 Re)*

	List-I		List-II
A.	(i) NaOH (ii) CO_2 (iii) H^+	I.	Benzoquinone
B.	(i) Aqueous NaOH + $CHCl_3$ (ii) H^+	II.	Benzene
C.	Zn dust, Δ	III.	Salicyl aldehyde
D.	$Na_2Cr_2O_7$, H_2SO_4	IV.	Salicylic acid

Choose the **correct answer** from the options given below:

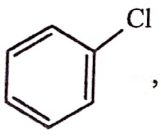
a. A-IV, B-II, C-I, D-III b. A-III, B-IV, C-I, D-II
c. A-II, B-I, C-IV, D-III d. A-IV, B-III, C-II, D-I

31. Which one of the following reaction sequence is **incorrect** method to prepare phenol? *(2022 Re)*

a.  , oleum, NaOH, H_3O^+.

b. Aniline, $NaNO_2$ + HCl, H_2O, heating

c. Cumene, O_2, H_3O^+

d.  , NaOH, STP condition

32. Given below are two statements: *(2022)*

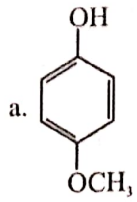
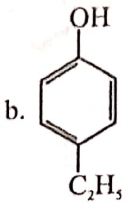
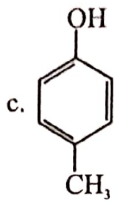
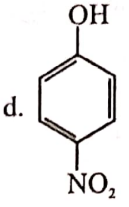
Statement-I: The acidic strength of monosubstituted nitrophenol is higher than phenol because of electron withdrowing nitro group.

Statement-II: o-nitrophenol, m-nitrophenol and p-nitrophenol will have same acidic strength as they have one nitro group attached to the phenolic ring.

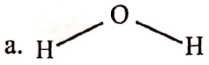
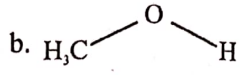
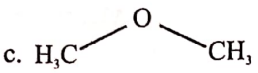
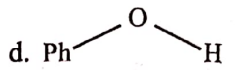
In the light of the above statements, choose the **most appropriate** answer form the options given below:

a. Statement-I is incorrect but Statement-II is correct.
b. Both Statement-I and Statement-II are correct.
c. Both Statement-I and Statement-II are incorrect.
d. Statement-I is correct but Statement-II is incorrect.

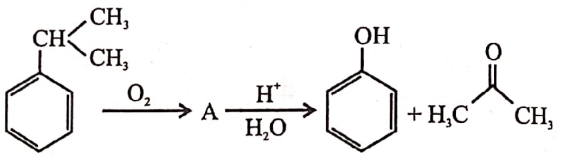
33. Which of the following substituted phenols is the strongest acid? **[MR*]** *(2020-Covid)*

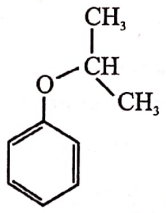
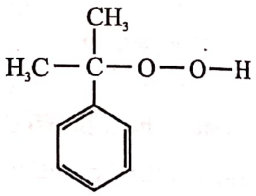
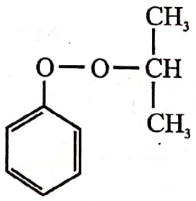
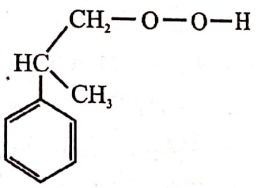
a. 
b. 
c. 
d. 

34. The compound that is most difficult to protonate is: *(2019)*

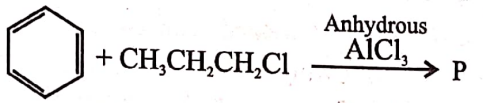
a. 
b. 
c. 
d. 

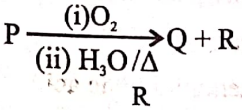
35. The structure of intermediate A in the following reaction, is *(2019)*



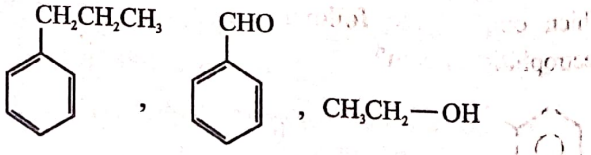
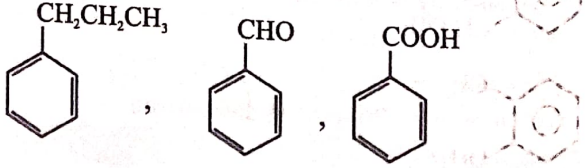
a. 
b. 
c. 
d. 

36. Identify the major products P, Q and R in the following sequence of reactions: **[MR*]** *(2018)*





P Q R

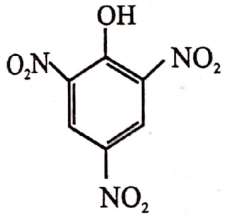
a. 
b. 

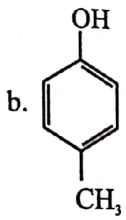
b. Formyl cation $\left(\overset{\oplus}{C}HO\right)$

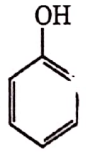
c. Dichlorocarbene $(:CCl_2)$

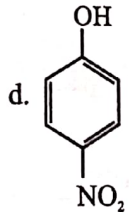
d. Dichloromethyl anion $\left(\overset{\oplus}{C}HCl_2\right)$

38. Which one is the most acidic compound? *(2017-Delhi)*

a. 

b. 

c. 

d. 

39. Reaction of phenol with chloroform in presence of dilute sodium hydroxide finally introduces which one of the following functional group? *(2015 Re)*

a. –CHO b. $-CH_2Cl$

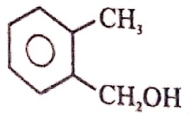
c. –COOH d. $-CHCl_2$

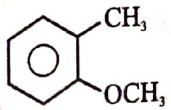
40. Which of the following will not be soluble in sodium hydrogen carbonate? *(2014)*

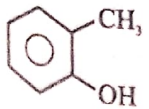
a. Benzoic acid b. o-Nitrophenol

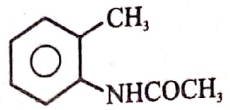
c. Benzenesulphonic acid d. 2,4,6-trinitrophenol

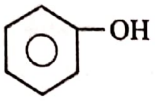
41. Which one of the following is most reactive towards electrophilic reagent? **[MR*]** *(2011 Pre)*

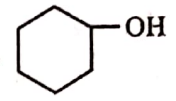
a. 

b. 

c. 

d. 

c. 

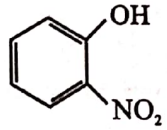
d. 

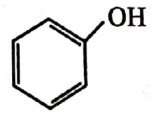
44. Given are cyclohexanol (I), acetic acid (II), 2, 4,6-trinitrophenol (III) and phenol (IV). In these the order of decreasing acidic character will be: *(2010 Pre)*

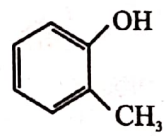
a. III > II > IV > I b. II > III > I > IV

c. II > III > IV > I d. III > IV > II > I

45. Which one of the following compounds is most acidic? *(2005)*

a. $Cl-CH_2-CH_2-OH$ b. 

c. 

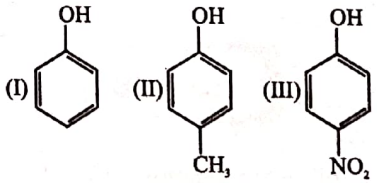
d. 

46. When phenol is treated with $CHCl_3$ and NaOH, the product formed is: *(2002)*

a. Benzaldehyde b. Salicyaldehyde

c. Salicylic acid d. Benzoic acid

47. The correct acidic order of following is: *(2001)*



a. I > II > III b. III > I > II

c. II > III > I d. I > III > II

48. Which of the following statement is correct for the stability of ions of ethyl alcohol and phenol? *(2000)*

a. Delocalisation of π-electrons in phenoxide ion

b. Delocalisation of electrons in ethoxide ion

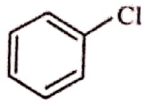
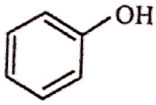
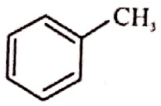
c. Inductive effect of ethyl and phenyl group

d. Localisation of π -electrons in phenoxide ion

49. The most suitable method of the separation of a mixture of ortho and para-nitrophenol mixed in the ratio of 1 : 1 is: *(1999)*

a. Distillation
b. Crystallisation
c. Vaporisation
d. Colour spectrum

50. Which of the following compounds will be more easily attacked by an electrophile? *(1999)*

a.
b. 
c. 
d. 

51. Aspirin is an acetylation product of: *(1998)*

a. o-hydroxybenzoic acid
b. o-hydroxybenzene
c. m-hydroxybenzoic acid
d. p-dihydroxybenzene

52. Increasing order of acid strength among *p*-methoxyphenol, *p*-methylphenol and *p*-nitrophenol is: *(1993)*

a. *p*-nitrophenol, *p*-methoxyphenol, *p*-methyl phenol
b. *p*-methylphenol, *p*-methoxyphenol, *p*-nitrophenol
c. *p*-nitrophenol, *p*-methylphenol, *p*-methoxyphenol
d. *p*-methoxyphenol, *p*-methylphenol, *p*-nitrophenol

53. When phenol is treated with excess bromine water. It gives: *(1992)*

a. *m*-bromophenol
b. *o*-and *p*-bromophenols
c. 2, 4-dibromophenol
d. 2, 4, 6-tribromophenol

54. Which one of the following compounds will be most readily attacked by an electrophile? *(1989)*

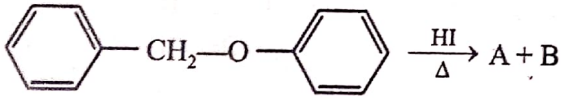
a. Chlorobenzene
b. Benzene
c. Phenol
d. Toluene

55. Phenol is heated with $CHCl_3$ and aqueous KOH when salicyaldehyde is produced. This reaction is known as: *(1989, 88)*

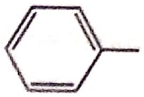
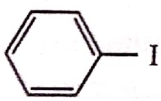
a. Rosenmund's reaction
b. Reimer-Tiemann reaction
c. Friedel-Crafts reaction
d. Sommelet reaction.

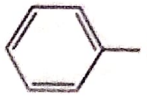
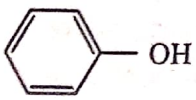
Ethers

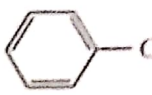
56. Consider the following reaction **[MR*]** *(2023)*

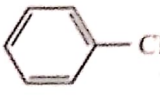


Identify products A and B

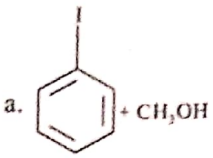
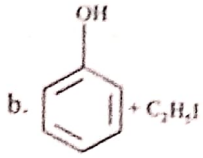
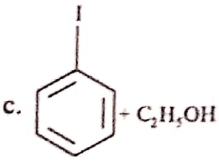
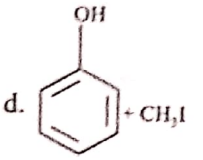
a. A =  and B = 

b. A =  and B = 

c. A =  and B =

d. A =  and B =

57. Anisole on cleavage with HI gives: *(202*

a. 
b. 
c. 
d. 

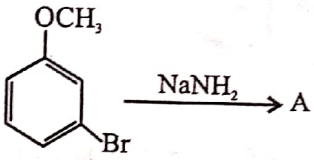
58. The compound A on treatment with Na gives B, and with PCl_5 gives C. B and C react together to give diethyl ether. A, B and C are in the order: **[MR*]** *(20*

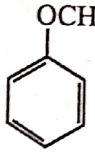
a. C_2H_5OH, C_2H_6, C_2H_5Cl
b. C_2H_5OH, C_2H_5Cl, C_2H_5ONa
c. C_2H_5OH, C_2H_5ONa, C_2H_5Cl
d. C_2H_5Cl, C_2H_6, C_2H_5OH

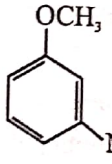
59. The heating of phenyl-methyl ethers with HI produces *(2017-Delhi*

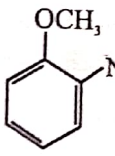
a. Benzene
b. Ethyl chlorides
c. Iodobenzene
d. Phenol

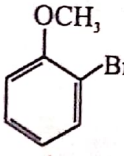
60. Identify A and predict the type of reaction: *(2017-Delhi*



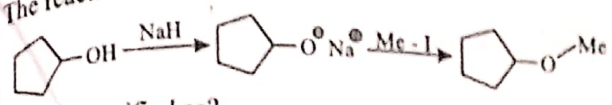
a.  and cine substitution reaction

b.  and substitution reaction

c.  and elimination addition reaction

d.  and cine substitution reaction

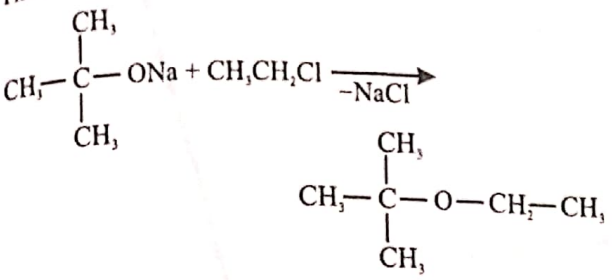
61. The reaction:



can be classified as? *(2016 - I)*

a. Williamson alcohol synthesis reaction
b. Williamson ether synthesis reaction
c. Alcohol formation reaction
d. Dehydration reaction

62. The reaction



is called: *(2015)*

a. Williamson continuous esterification process
b. Etard reaction
c. Gatterman - Koch reaction
d. Williamson synthesis

63. Among the following sets of reactants which one produces anisole? *(2014)*

a. C_6H_5OH; NaOH; CH_3I
b. C_6H_5OH; neutral $FeCl_3$
c. $C_6H_5 - CH_3$; CH_3COCl; $AlCl_3$
d. CH_3CHO; RMgX

64. Identify Z in the sequence of reactions:

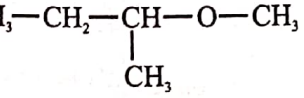
$$CH_3CH_2CH = CH_2 \xrightarrow{HBr/H_2O_2} Y \xrightarrow{C_2H_5ONa} Z$$

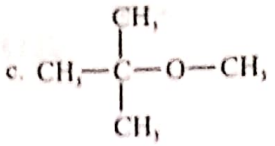
[MR*] *(2014)*

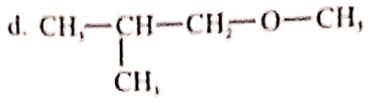
a. $(CH_3)_2CH - O - CH_2CH_3$
b. $CH_3(CH_2)_4 - O - CH_3$
c. $CH_3CH_2 - CH(CH_3) - O - CH_2CH_3$
d. $CH_3 - (CH_2)_3 - O - CH_2CH_3$

65. Among the following ethers, which one will produce methyl alcohol on treatment with hot concentrated HI? *(2013)*

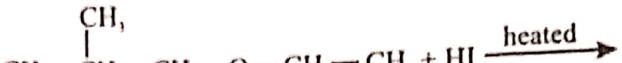
a. $CH_3 - CH_2 - CH_2 - CH_2 - O - CH_3$

b. 

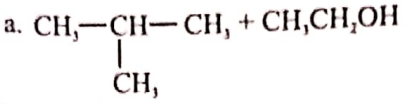
c. 

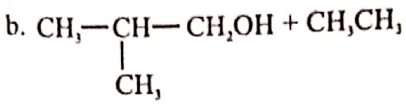
d. 

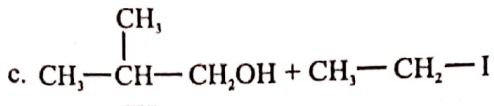
66. In the reaction:

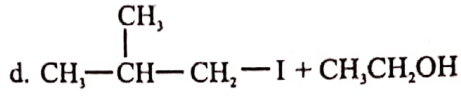


Which of the following compounds will be formed? *(2007)*

a. 

b. 

c. 

d. 

67. The major organic product in the reaction, $CH_3 - O - CH(CH_3)_2 + HI \rightarrow$ Product is: *(2006)*

a. $CH_3OH + (CH_3)_2CHI$ b. $ICH_2OCH(CH_3)_2$
c. $CH_3OC(CH_3)_2$ d. $CH_3I + (CH_3)_2CHOH$

68. Ethyl chloride is converted into diethyl ether by: *(1999)*

a. Wurtz synthesis b. Grignard reaction
c. Perkin's reaction d. Williamson's synthesis

69. Which one of the following compounds is resistant to nucleophilic attack by hydroxyl ions? *(1998)*

a. Methyl acetate b. Acetonitrile
c. Dimethyl ether d. Acetamide

70. The compound which does not react with sodium is: *(1994)*

a. CH_3COOH b. $CH_3CHOHCH_3$
c. C_2H_5OH d. CH_3OCH_3

71. Which one is formed when sodium phenoxide is heated with ethyl iodide? *(1988)*

a. Phenetole b. Ethyl phenyl alcohol
c. Phenol d. None of these

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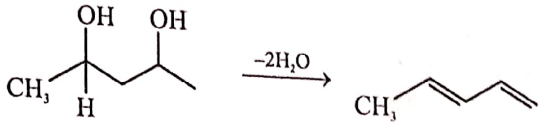
1. (c)



Formation of Conjugated diene in option (c) make the given reactant most reactive towards dehydration in acidic conditions.

2. (a) Here 'X' will be B_2H_6.

$$R\text{–}COOH \xrightarrow[(ii)\ H_2O/HCl]{(i)\ B_2H_6} R\text{–}CH_2OH$$

$$R\text{–}CH{=}CH_2 \xrightarrow[(ii)\ H_2O,\ NaOH.H_2O_2]{(i)\ B_2H_6} R\text{–}CH_2\text{–}CH_2\text{–}OH$$

3. (c) Reagents given in (A), (B) and (C) convert alcohols to carboxylic acids.

$$R\text{–}CH_2\text{–}OH \xrightarrow[K_2Cr_2O_7-H_2SO_4\ or]{CrO_3-H_2SO_4\ or} R\text{–}COOH$$

$KMnO_4 + KOH/H_3O^+$
(Strong oxidising agents)

4. (d) Primary, secondary and tertiary alcohols are distinguished by Lucas test on the basis of the time taken for turbidity to appear

$$R\text{–}CH_2\text{–}OH \xrightarrow{Conc.\ HCl + Anhy.ZnCl_2} R\text{–}CH_2\text{–}Cl$$

1° alcohol — (Turbidity in 30 min.)

$$\begin{matrix}R\\R\end{matrix}\!\!>\!CH_2\text{–}OH \xrightarrow{Conc.\ HCl + Anhy.ZnCl_2} \begin{matrix}R\\R\end{matrix}\!\!>\!CH_2\text{–}Cl$$

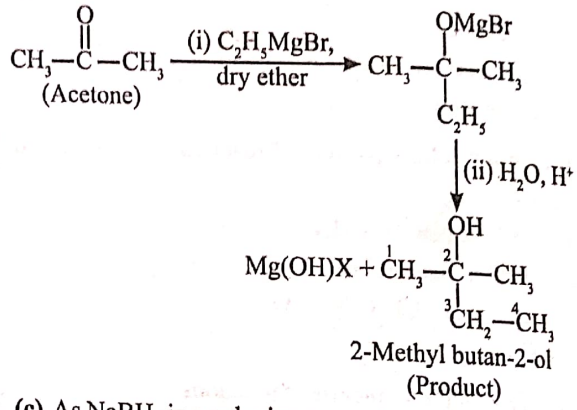
2° alcohol — (Turbidity in 5 min.)

$$\begin{matrix}R\\R\\R\end{matrix}\!\!>\!CH_2\text{–}OH \xrightarrow{Conc.\ HCl + Anhy.ZnCl_2} \begin{matrix}R\\R\\R\end{matrix}\!\!>\!CH_2\text{–}OH$$

3° alcohol — (Immediate turbidity appears)

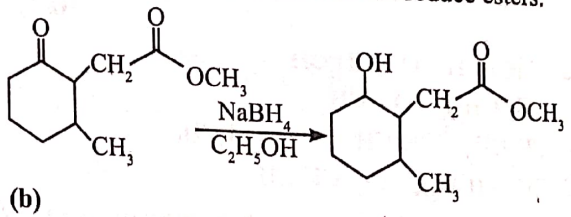
Hence, reactivity of alcohols toward Lucas regent is $3° > 2° > 1°$

5. (c)

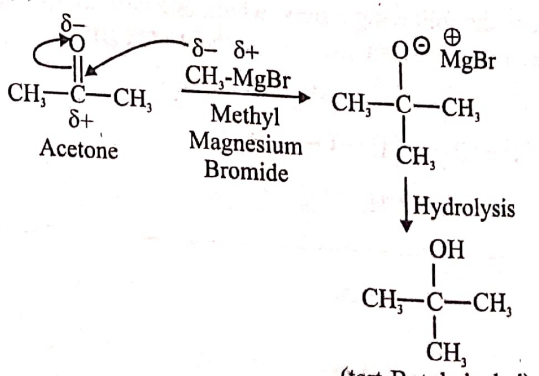


(Acetone) — 2-Methyl butan-2-ol (Product)

6. (c) As $NaBH_4$ is a reducing agent, hence it will reduce ketone into secondary alcohol but it will not reduce esters.

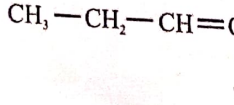


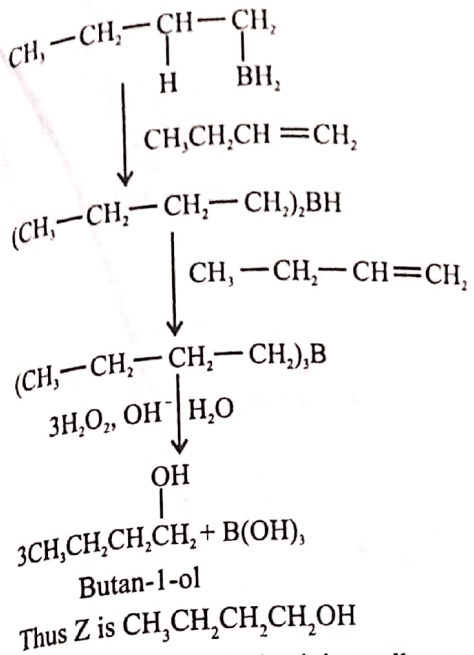
7. (b)



Acetone — Methyl Magnesium Bromide — (tert-Butyl alcohol)

8. (d) The given reaction is hydroboration–oxidation reaction. It is a two-step hydration reaction that converts an alkene into an alcohol.



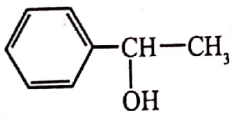


Butan-1-ol

Thus Z is $CH_3CH_2CH_2CH_2OH$

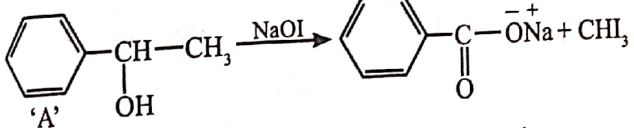
9. (c) As the compound is giving yellow precipitate with NaOI that shows it is undergoing haloform reaction. Haloform reaction is shown by the compounds having

$CH_3-\underset{\underset{O}{\|}}{C}-$ or $CH_3-\underset{\underset{OH}{|}}{CH}-$ group

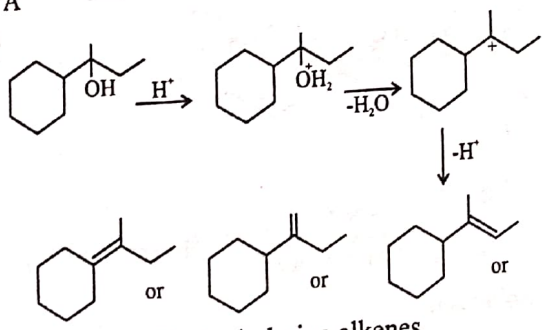
Hence, the compound A is 

$$2NaOH + I_2 \rightarrow NaOI + NaI + H_2$$

'Y'

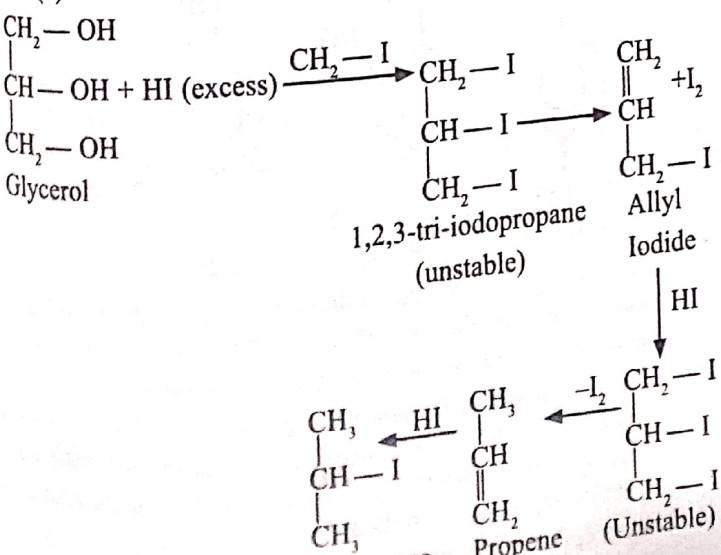


10. (a)



Dehydration of 3° alcohol give alkenes.

11. (a)



12. (c) $CH_3CH_2OH \xrightarrow{PBr_3} CH_3-CH_2-Br \xrightarrow[KOH]{alc.}$

$$CH_2=CH_2 \xrightarrow[H_2O]{H_2SO_4} CH_3CH_2OH$$

13. (a) A series of similarly constituted compounds in which the members possess the same functional group and have similar chemical characteristics. The two consecutive members differ in their molecular formula by $-CH_2$ group.

General formula of homolgous series of alkanols.

$C_nH_{2n+2}O$

Put n = 1, CH_3OH methanol

n = 2, C_2H_5OH ethanol

Methanol, ethanol are Homologous to each other. Since they differ by $-CH_2$ group.

14. (a) $CH_2-CH_2 + CH_3MgBr \rightarrow$

ethylene oxide Grignard Regent

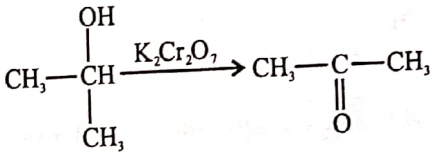
$$CH_3CH_2CH_2OMgBr \xrightarrow{H^+} CH_3CH_2CH_2OH$$

Primary alcohol.

15. (b) Formation of yellow precipitate on heating a compound with an alkaline solution of iodine is known as Iodoform reaction. For Iodoform test compound should have $\left(CH_3-\underset{\underset{O}{\|}}{C}-\right)$ group or CH_3CH_2OH group. Methyl alcohol do not respond to this test.

16. (c) $CH_3CH_2CH_2OH \xrightarrow[H_2SO_4]{\text{(Potassium dichromate) } K_2Cr_2O_7} CH_3CH_2CHO$

Isopropyl alcohol on oxidation gives ketone.



17. (c) $C_2H_5OH + 4I_2 + NaOH \rightarrow CHI_3 + NaI + HCOONa + H_2O$.

Iodoform is a pale yellow solid which crystallises in hexagonal plates.

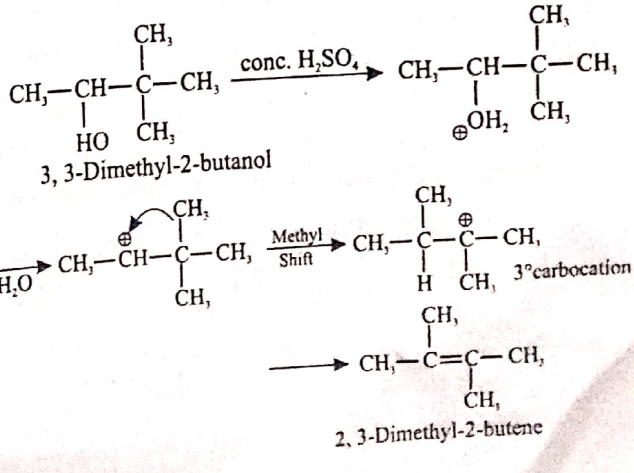
18. (c) $CH_3-CH_2 + R-Mgx \rightarrow R-CH_2-CH_2-O-MgX$

Ethylene oxide

$$R-CH_2-CH_2-OH \xleftarrow{H_2O/H^+} R-CH_2-CH_2-O-MgX$$

1° alcohol + $Mg(OH)X$ ← 1° alconol

19. (a)



20. (a) $CH_2OH-CHOH-CH_2OH \xrightarrow{\text{conc. } H_2SO_4} CH_2=CHCHO + 2H_2O$

Glycerol → Acrolein

Dehydration takes place in the presence of H_2SO_4.

21. (a) Hydrogen bonding in ethanol. Due to this B. pt. of alcohol is higher than the ether.

22. (b) 2^0 alcohols on oxidation give ketones, 1° alcohols form aldehydes.

23. (a) Primary alcohol undergoes catalytic dehydrogenation to give aldehyde.

24. (b) (i) $CH_3CH_2CH_2CH_2CH_2OH$

(ii) $CH_3CH_2-CH(CH_3)-CH_2OH$

(iii) $CH_3-CH(CH_3)-CH_2-CH_2OH$

(iv) $CH_3-C(CH_3)_2-CH_2OH$

There are four isomers of 1° alcohol.

25. (d) $CO + 2H_2 \xrightarrow{ZnO-Cr_2O_3} CH_3OH$

26. (b) $CH_3-C(CH_3)(OH)-CH_3$

This is very stable intermediate, thus it will react more rapidly with HBr.

27. (d) 2-Methylpropan-2-ol (3°alcohol) reacts rapidly with Lucas reagent at room temperature.

$$CH_3-C(CH_3)_2-OH \xrightarrow{H^+} CH_3-C^{\oplus}(CH_3)_2 \xrightarrow{Br^-} CH_3-C(CH_3)_2-Br$$

2-Methyl-2-propanol

28. (c) $CH_3-CH=CH_2 \xrightarrow[\text{Hydroboration}]{BH_3, THF} (CH_3CH_2CH_2)_3B$

Tripropyl borane

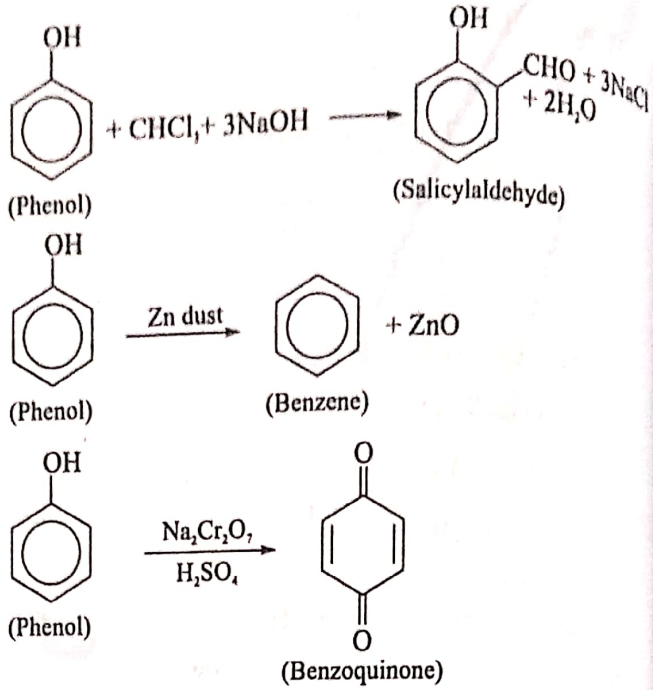
$\xrightarrow[OH^-]{H_2O_2} 3CH_3CH_2CH_2OH$

Propan-1-ol

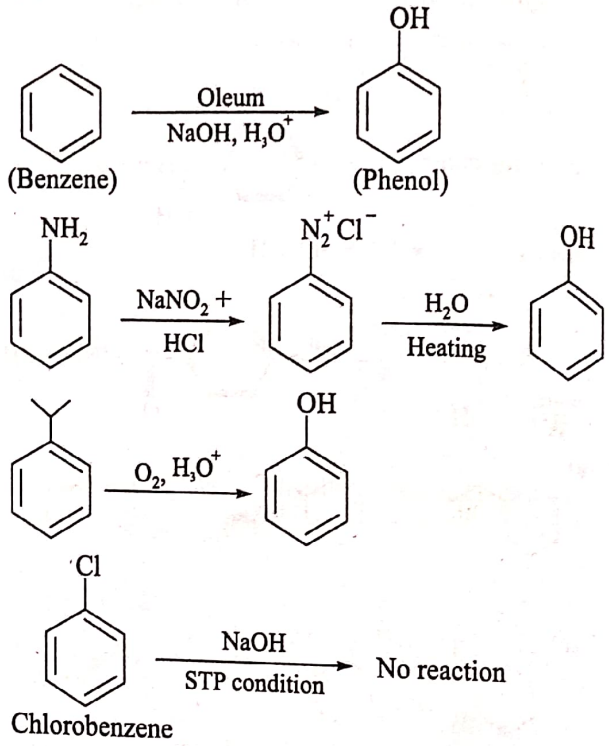
This reaction is known as hydroboration-oxidation reaction.

29. (a) Conc. HCl and anhydrous $ZnCl_2$ - Lucas reagent.

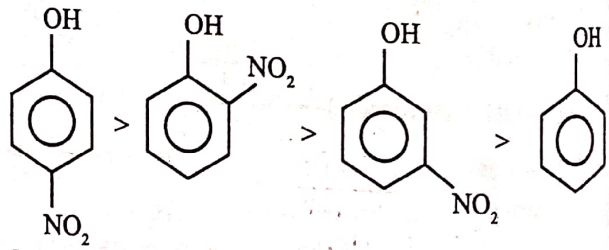
30. (d) Phenol $\xrightarrow{NaOH}$ Sodium phenoxide $\xrightarrow[(ii)\ H^+]{(i)\ CO_2}$ Salicylic acid (2-hydroxybenzoic acid)



31. (d)



32. (d)

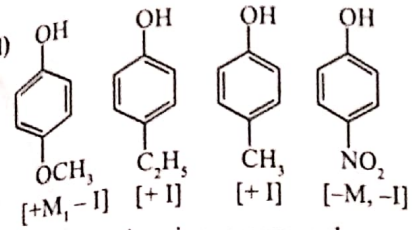


As nitro group is electron-withdrawing group. It will withdraws electron density through –R and –I effect but –R is not operated at meta position. So meta-nitrophenol is least acidic.

If we compare ortho and para, para is more acidic because in case of ortho intra Molecular H-bonding will take place. The loss of proton is more difficult due to Intra molecular H-bonding in ortho product.

Hence, Para-nitro phenol is more acidic.

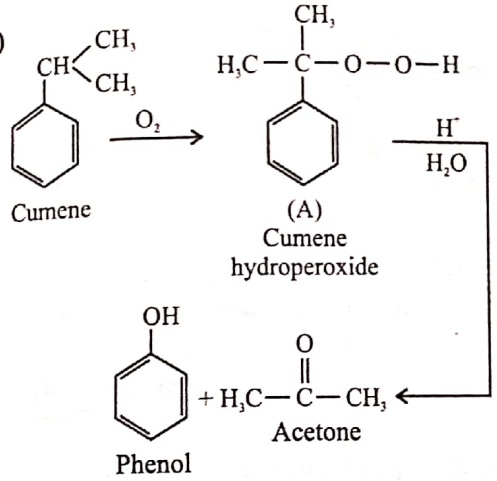
33. (d)



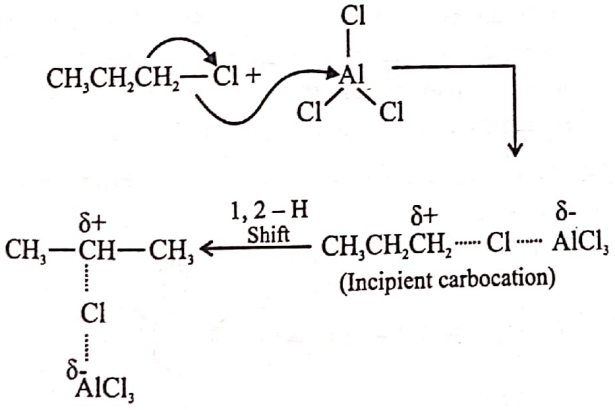
Electron-withdrawing group enhance the acidity. As, it with draw's electron-density towards itself and stabilise the phenoxide ion due to this acidity increase while electron-donating group decrease the acidic-strength.

34. (d) Due to involvement of lone pair of electrons present on O-atom is in resonance in phenol. So, it will have positive charge (partial), hence incoming proton will not be able to attack easily.

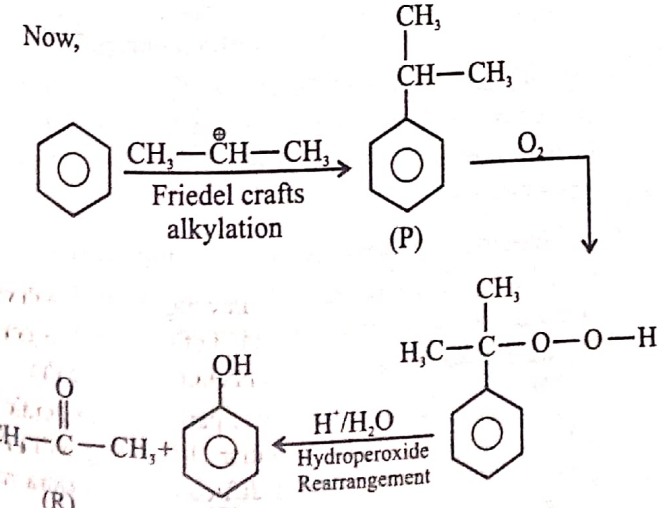
35. (b)



36. (c)



Now,

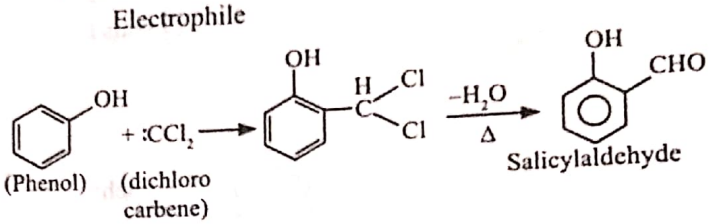


37. (c) It is Reimer-Tiemann reaction the electrophile formed is :CCl_2 (Dichlorocarbene) according to the following reaction

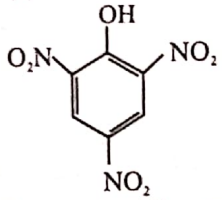
$$CHCl_3 + OH^- \rightleftharpoons \ddot{C}Cl_3 + H_2O$$

$$\ddot{C}Cl_3 \longrightarrow :CCl_2 + Cl^-$$

Electrophile

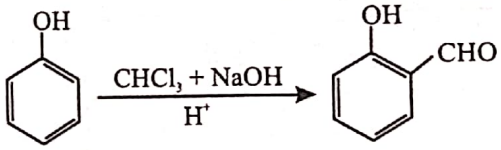


38. (a)



Is a most acidic compound. $-NO_2$ is an electron withdrawing group. In this compound, NO_2 is attached to the ortho and para position which increases the acidic strength of phenol. It withdraw's the electron density towards itself and stabilize the phenoxide ion.

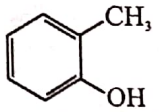
39. (a)



The above reaction is Riemer - Tiemann reaction which introduces a –CHO (aldehyde) group to phenol.

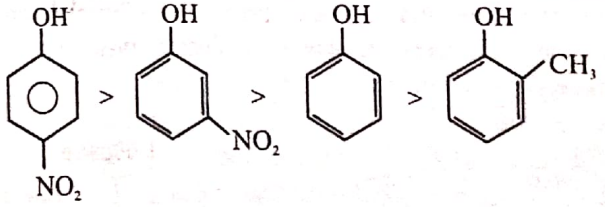
40. (b) Sodium hydrogen carbonate ($NaHCO_3$) being an alkali solution will dissolve an acid not a base so o-nitrophenol (due to presence of intramolecule H-bonding) being a very weak acid than $NaHCO_3$ will not get dissolve.

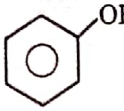
41. (c) For an electrophilic reagent, a (–ve) charge or at target specie must be present.

Among the 4 options 

will be most suitable for eletrophilic reaction, here lone pair of oxygen are in conjugation with benzene ring & $-CH_3$ group imparts +R effect.

42. (a) When electron withdrawing group like – NO_2, CHO is present on the benzene ring, it tend to increase the acidity.



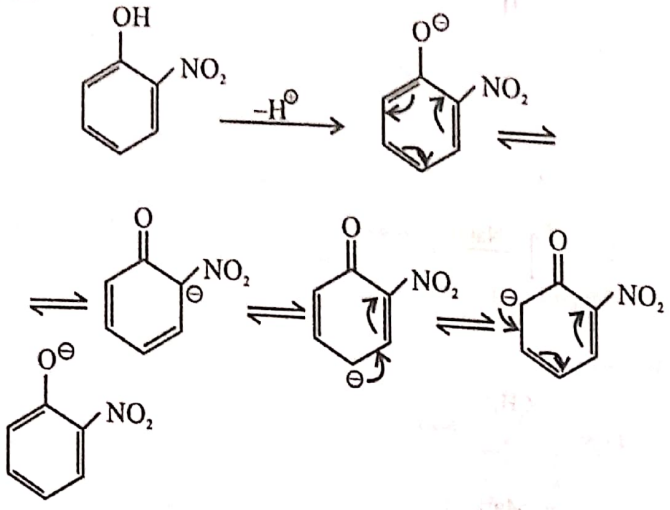
43. (c) 

is the most acidic compound as the phenoxide formed is resonance stabilized.

44. (a) III > II > IV > I

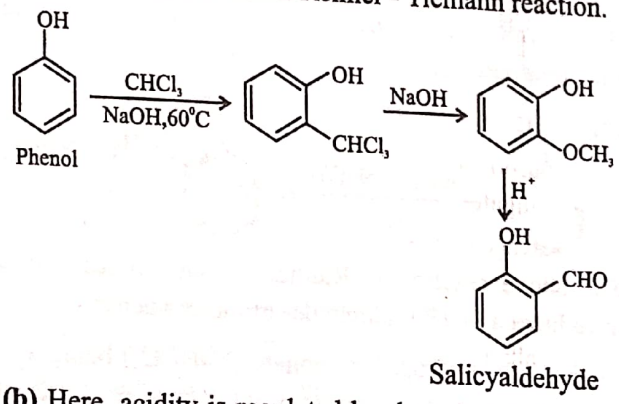
Since, phenols and carboxylic acids are more acidic than aliphatic alcohols, we find that cyclohexanol (I) is least acidic.

45. (b)



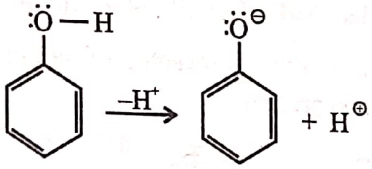
More the number of resonating structures, more the stability. Here, phenoxide ion formed is stabilised by resonance and strong electron withdrawing effect of $-NO_2$ group.

46. (b) This reaction is called Reimer - Tiemann reaction.



Salicyaldehyde

47. (b) Here, acidity is regulated by the ease of deproto nation and the extent of stability of the anion.

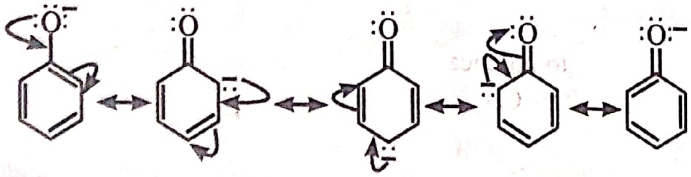


Phenoxide ion

Phenoxide ion is already very stable due to its resonating structures and when an electron - withdrawing group ($-NO_2$, $-CN$) is present, it increases the acidity of phenol.

When electron donating group ($-NH_2$, $-CH_3$) is present, it decreases the acidity of phenol.

48. (a) Phenoxide ion is more stable than ethoxide ion due to resonance. Therefore, the ionisation constant of phenol is higher than ethanol.

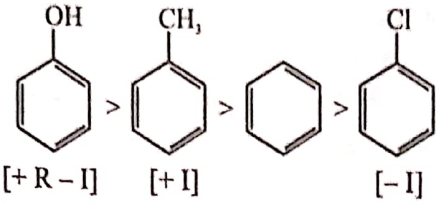


$C_2H_5-O-H \rightleftharpoons C_2H_5-O^- + H^+$

Stable — Not stable ethoxide ion (due to absence of resonance)

49. (a) Due to difference in boiling point ortho and para position of nitrophenol can be separated from each other by distillation.

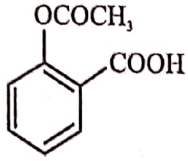
50. (c) OH group in phenol can release electrons to ring better than $-CH_3$ group in toluene. Order of electrophillic substitution reaction



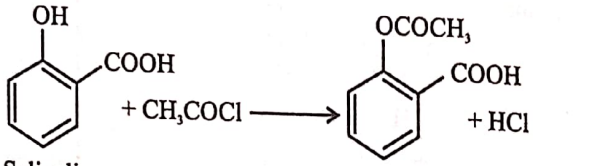
[+ R – I] [+ I] [– I]

More the electron density on the benzene ring more easily the attack by electrophile take place. Donation by +R is dominating than donation by +I.

51. (a) Aspirin is



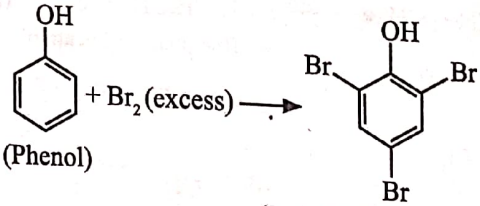
which is acetylated product of salicylic acid (o - hydroxy benzoic acid)



Salicylic acid — Acetyl salicylic acid (Aspirin)

52. (d) $-OCH_3$ (Strong electron donor due to +M effect) $-CH_3$ are electron donating groups and decreases the acidic character of phenols. $-NO_2$, $-CN$ are electron withdrawing group, tend to increase the acidic character. Thus, the order is *p*-methoxyphenol < *p*-methylphenol < *p*-nitrophenol.

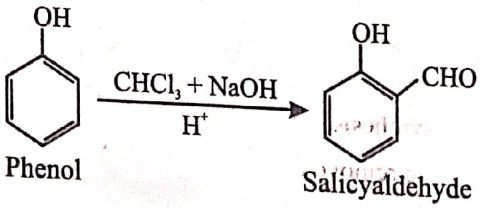
53. (d) Phenol on reaction with excess bromine water give 2,4,6-tribromophenol.



(Phenol) — (2, 4, 6-tribromophenol)

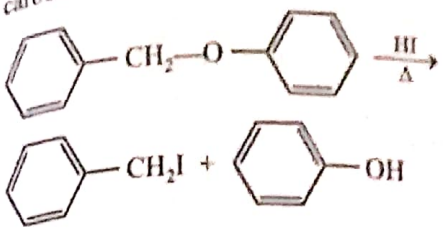
54. (c) –OH group being strong electron donor due to +M effect increases the electron density in phenol. Thus, the electron density in phenol is higher than that of toluene, benzene and chlorobenzene.

55. (b) Treatment of phenol with $CHCl_3$ and aqueous hydroxide introduces –CHO group, into the aromatic ring generally ortho to the –OH group. This reaction is known as Reimer - Tiemann reaction.

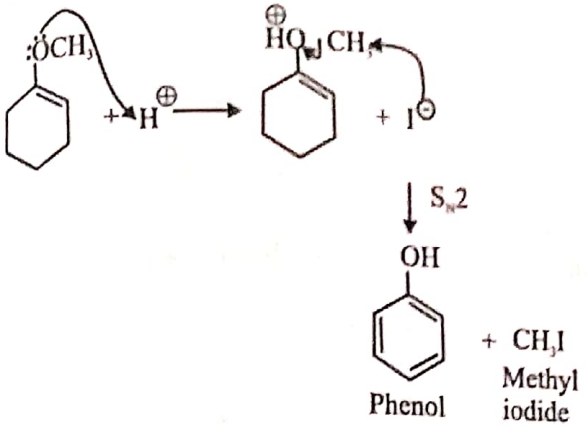


Phenol — Salicyaldehyde

56. (d) Reaction follows S_N1 pathway involving Benzylic carbocation.



57. (d) Anisole on cleavage with HI gives phenol and methyliodide

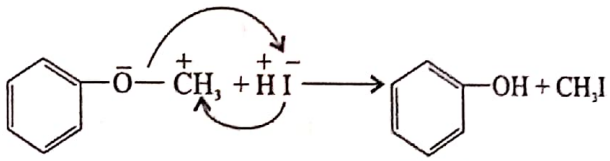


58. (c) $C_2H_5OH \xrightarrow{Na} C_2H_5O^- Na^+$ (A) → (B)

(A) $\xrightarrow{PCl_5}$ C_2H_5Cl (C)

$C_2H_5O^- Na^+$ (B) + C_2H_5Cl (C) $\xrightarrow{S_N2}$ $C_2H_5OC_2H_5$ Diethyl ether

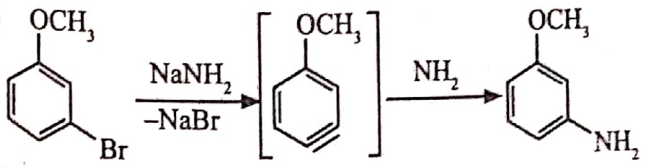
59. (d)



Phenyl methyl ether — Phenol

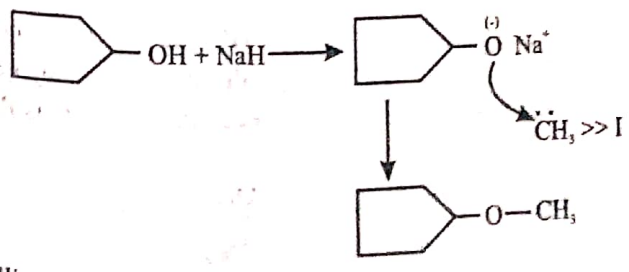
In phenyl methyl ether C-O bond is sp^2 hybridised. In sp and sp^2 hybridisation ($C_{large} - O - C_{small}$) cleavage takes place but in sp^3 hybridisation ($C_{large} - O - C_{small}$) cleavage takes place.

60. (b)



This reaction is a substitution reaction.

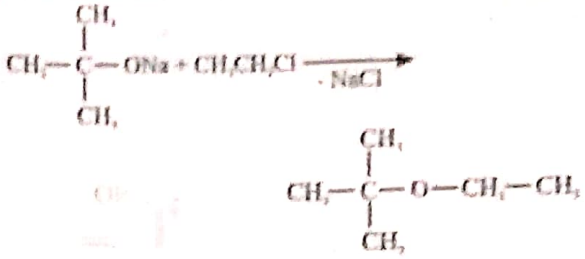
61. (b)



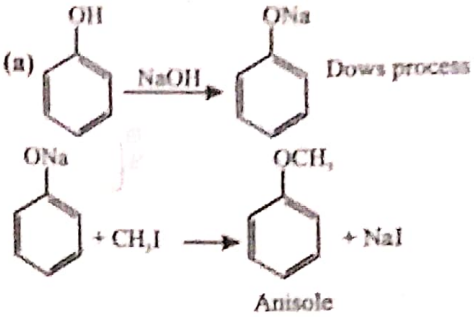
Williamson ether synthesis

NaH is a base which remove the 'H' of 'OH' group.

62. (d) The above reaction is called Williamson synthesis of ether.



63. (a)



64. (d) In anti Markonikov reaction (presence of peroxide linkage):

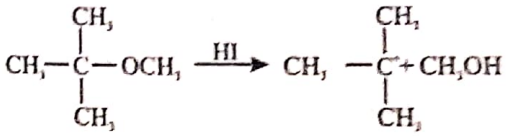
$CH_3CH_2CH = CH_2 + HBr/H_2O_2 \rightarrow CH_3CH_2–CH_2–CH_2Br$

For ether formation:

$C_2H_5ONa \rightarrow CH_3CH_2–CH_2–CH_2–O–C_2H_5 + NaBr$

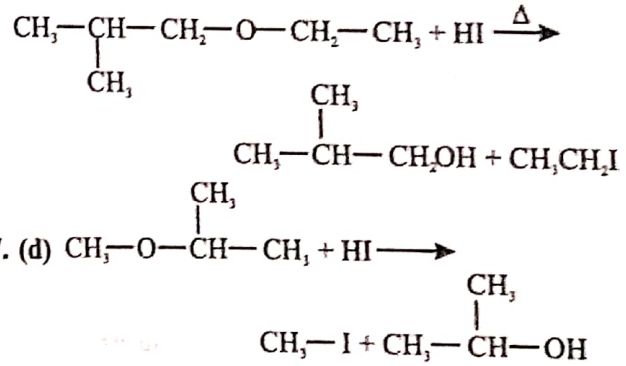
Williamson synthesis

65. (c)



As 3° carbocation formed is stabilized because of 9 hyperconjugated H's and 3 inductive effect inducing $–CH_3$.

66. (c) In cleavage of ether with two different alkyl groups, alcohol and alkyl iodide that are formed depends on the nature of alkyl group. When primary or secondary alkyl groups are present, it is the lower alkyl group that forms alkyl iodide therefore:



67. (d)

68. (d) $C_2H_5Cl + NaOC_2H_5 \downarrow C_2H_5 – O – C_2H_5 + NaCl$

It is williamson's synthesis.

69. (c) Dimethyl ether does not show nucleophillic attack due to absence of multiple bond.

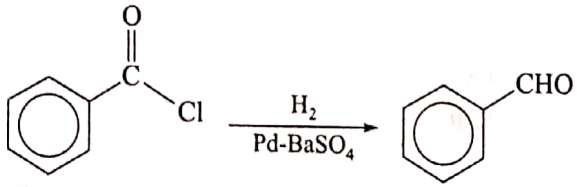
70. (d) Ethers are very inert. The chemical inertness of ethers is due to absence of active group in their molecules. Since $CH_3 – O – CH_3$ is inert and it does not contain active group, therefore it does not react with sodium.

71. (a) Phenetole is formed when sodium phenoxide is heated with ethyl iodide.

$C_6H_5ONa + C_2H_5I \xrightarrow{\Delta} C_6H_5OC_2H_5$

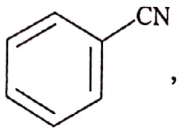
Phenetole

1. The following conversion is known is: *(2023-Manipur)*

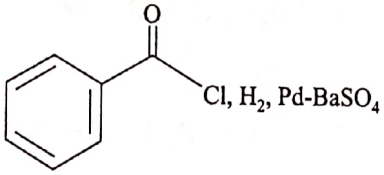


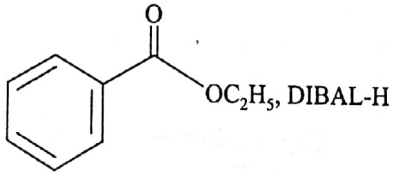
a. Stephen reaction
b. Gattermann-Koch reaction
c. Etard reaction
d. Rosenmund reaction

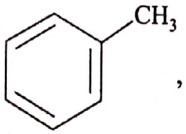
2. The incorrect method to synthesize benzaldehyde is: *(2022 Re)*

a. 

, CH_3MgBr, followed by H_3O^+

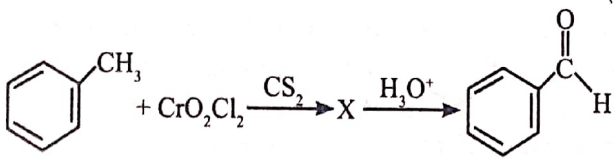
b. 

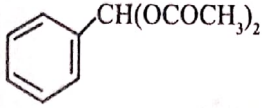
c. 

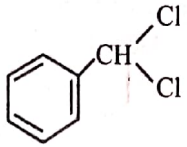
d. 

, CrO_2Cl_2, followed by H_3O^+ in CS_2

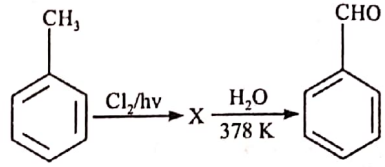
3. The intermediate compound 'X' in the following chemical reaction is: *(2021)*

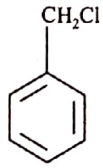


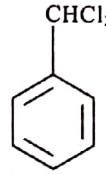
a. 

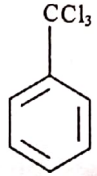
b. 

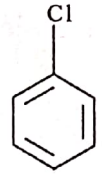
4. Identify compound X in the following sequence of reactions: **[MR*]** *(2020)*



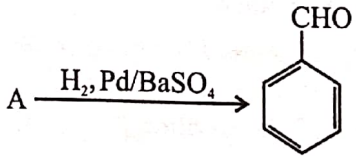
a. 

b. 

c. 

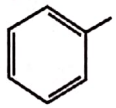
d. 

5. Identify compound (A) in the following reaction: *(2020-Covid)*

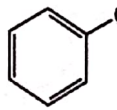


a. Toluene
b. Acetophenone
c. Benzoic acid
d. Benzoyl chloride

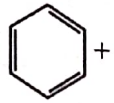
6. Reaction by which Benzaldehyde cannot be prepared: **[MR*]** *(2013)*

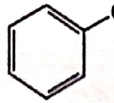
a. 

+ CrO_2Cl_2 in CS_2 followed by H_3O^+

b. 

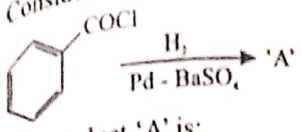
+ H_2 in presence of $Pd\text{-}BaSO_4$

c. 
+ CO + HCl in presence of anhydrous $AlCl_3$

d. 

+ Zn/Hg and concentration HCl

7. Consider the following reaction:



The product 'A' is: *(2012 Mains)*

a. C_6H_5Cl b. C_6H_5CHO

c. C_6H_5OH d. $C_6H_5COCH_3$

8. Which one of the following can be oxidised to the corresponding carbonyl compound? *(2004)*

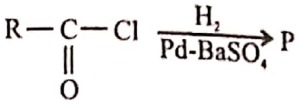
a. o-Nitrophenol

b. Phenol

c. 2-methyl-2-hydroxypropane

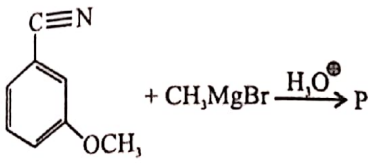
d. 2-hydroxypropane

9. In the following reaction product 'P' is: *(2002)*

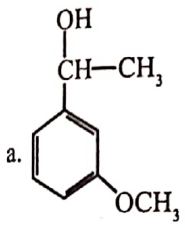


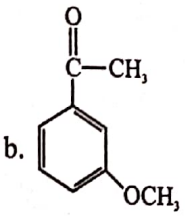
a. RCH_2OH b. RCOOH

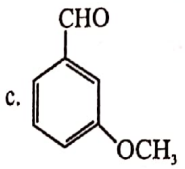
c. RCHO d. RCH_3

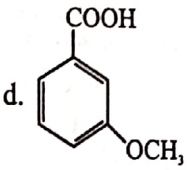
10. 

Product 'P' in the above reaction is: **[MR*]** *(2002)*

a. 

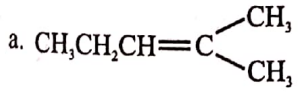
b. 

c. 

d. 

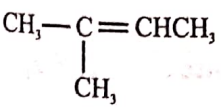
11. Which alkene on ozonolysis gives? **[MR*]** *(2001)*

CH_3CH_2CHO and $CH_3\overset{\overset{O}{\|}}{C}CH_3$

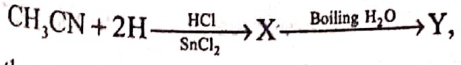
a. 

b. $CH_3CH_2CH = CHCH_2CH_3$

c. $CH_3CH_2CH = CHCH_3$

d. 

12. In the reaction



the term Y is: *(1999)*

a. Acetone b. Ethanamine

c. Acetaldehyde d. Dimethyl amine

13. When acetylene is passed through dil. H_2SO_4 in presence of $HgSO_4$ the compound formed is: **[MR*]** *(1999)*

a. Ether b. Ketone

c. Acetic acid d. Acetaldehyde

14. Ketones ($RCOR_1$) where $R = R_1$ = alkyl group. It can be obtained in one step by: *(1997)*

a. Oxidation of tertiary alcohol

b. Reaction of acid halide with alcohols

c. Hydrolysis of esters

d. Oxidation of primary alcohol

15. The oxidation of toluene to benzaldehyde by chromyl chloride is called: *(1996)*

a. Etard reaction b. Riemer-Tiemann reaction

c. Wurtz reaction d. Cannizzaro's reaction

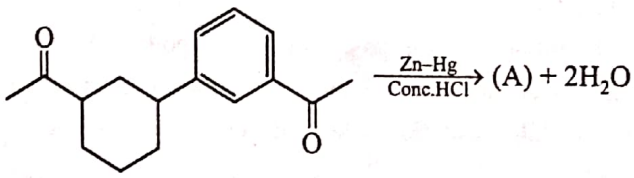
16. The oxidation of toluene with CrO_3 in the presence of $(CH_3CO)_2O$ gives a product *A*, which on treatment with aqueous NaOH produces: *(1995)*

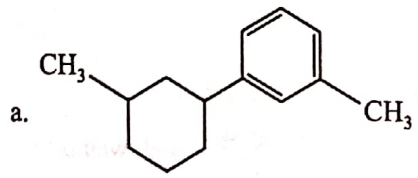
a. C_6H_5COONa b. 2, 4-diacetyl toluene

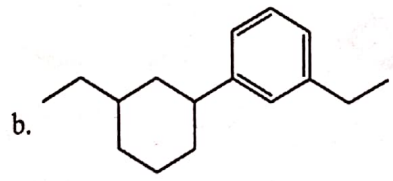
c. C_6H_5CHO d. $(C_6H_5CO)_2O$

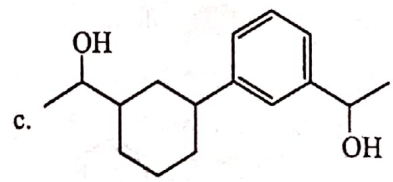
Physical Properties and Chemical Reactions of Aldehydes and Ketones

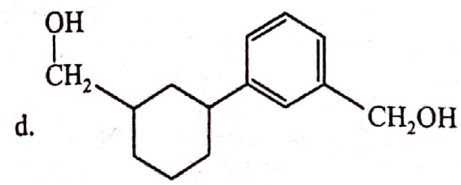
17. Identify product (A) in the following reaction: **[MR*]** *(2023)*



a. 

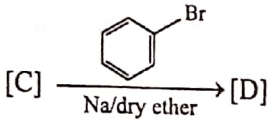
b. 

c. 

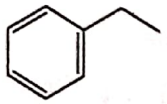
d. 

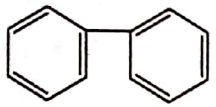
19. Identify the final product [D] obtained in the following sequence of reactions, [MR*] *(2023)*

$$CH_3CHO \xrightarrow[(ii)\ H_3O^+]{(i)\ LiAlH_4} [A] \xrightarrow[\Delta]{H_2SO_4} [B] \xrightarrow{HBr}$$



a. $HC \equiv C^-Na^+$

b. 

c. 

d. C_4H_{10}

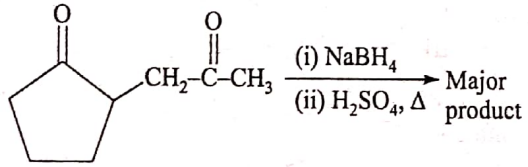
20. Consider the given reaction: *(2023-Manipur)*

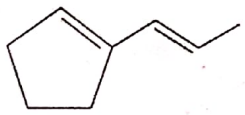
$$CH_3COCH_3 \xrightarrow{dil\ Ba(OH)_2} \text{“X”}$$

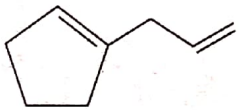
The functional groups present in compound “X” are:

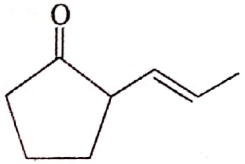
a. ketone are double bond
b. double bond and aldehyde
c. Alcohol and aldehyde
d. alcohol and ketone

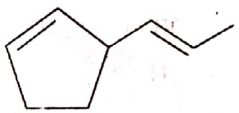
21. The **major** product formed in the following conversion is ..... . *(2023-Manipur)*



a. 

b. 

c. 

d. 

22. Which of the following reactions is not an example for nucleophilic addition – elimination reaction ? [MR*] *(2022 Re)*

a. $CH_3CHO + NH_3 \rightleftharpoons CH_3CH = NH + H_2O$

b. $CH_3CHO + NaHSO_3 \rightleftharpoons CH_3-\underset{H}{\overset{OH}{C}}-OSO_2Na$

c. $CH_3CHO + NaHSO_3 \rightleftharpoons CH_3-\underset{H}{\overset{OH}{C}}-SO_3Na$

d. $CH_3CHO + NaHSO_3 \rightleftharpoons CH_3-\underset{H}{\overset{OH}{C}}-SO_2Na$

23. Statements-I : Aldehydes are more reactive than ketones towards nucleophilic addition reactions.

Statements-II : Aldehydes are more polar than ketones.

a. Statements-I and Statements-II are correct
b. Statements-I and Statements-II are incorrect
c. Statements-I is incorrect but Statements-II is correct
d. Statements-I is correct but Statements-II is incorrect

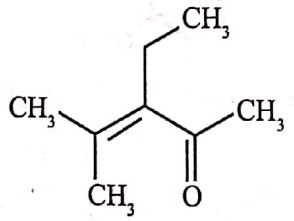
24. Match List-I with List-II. [MR*] *(2*

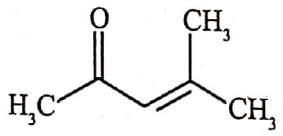
	List-I (Products formed)		List-II (Reaction of carbo compound with)
(a)	Cyanohydrin	(i)	NH_2OH
(b)	Acetal	(ii)	RNH_2
(c)	Schiff's base	(iii)	alcohol
(d)	Oxime	(iv)	HCN

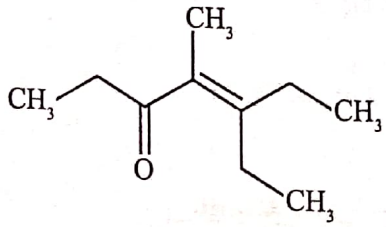
Choose the correct answer from the options given belo

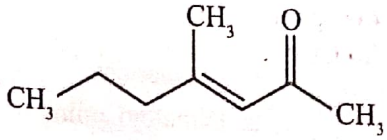
a. (a)-(iv), (b)-(iii), (c)-(ii), (d)-(i)
b. (a)-(iii), (b)-(iv), (c)-(ii), (d)-(i)
c. (a)-(ii), (b)-(iii), (c)-(iv), (d)-(i)
d. (a)-(i), (b)-(iii), (c)-(ii), (d)-(iv)

25. Which one of the following is not formed when ac reacts with 2-pentanone in the presence of dilute N followed by heating? *(2*

a. 

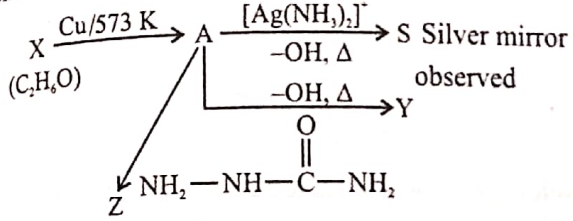
b. 

c. 

d. 

c.

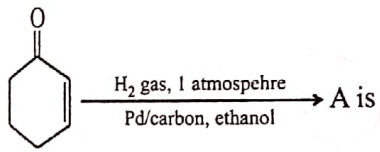
28. Consider the reactions: [MR*] *(2017-Delhi)*

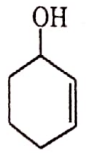
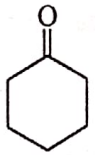
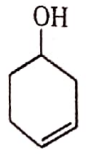
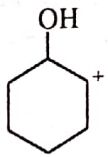


Identify A, X, Y and Z

a. A-Ethanol, X-Acetaldehyde, Y-Butanone, Z-Hydrazone
b. A-Methoxymethane, X-Ethanoic acid, Y-Acetate ion, Z-hydrazine
c. A-Methoxymethane, X-Ethanol, Y-Ethanoic acid, Z-Semicarbazide
d. A-Ethanal, X-Ethanol, Y-But-2-enal, Z-Semicarbazone

29. The correct structure of the product 'A' formed in the reaction *(2016 - II)*



a. 
b. 
c. 
d. 

30. The product formed by the reaction of an aldehyde with a primary amine is: *(2016 - I)*

a. Aromatic acid
b. Schiff base
c. Ketone
d. Carboxylic acid

31. Which of the following reagents would distinguish cis-cyclopenta-1, 2-diol from the trans-isomer? [MR*] *(2016 - I)*

a. MnO_2
b. Aluminium isopropoxide
c. Acetone
d. Ozone

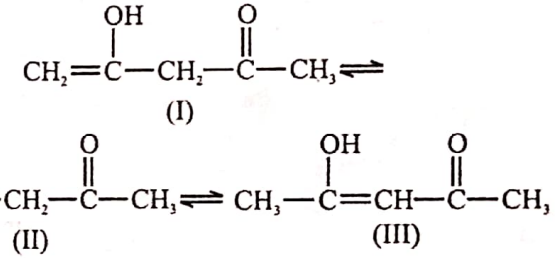
elimination of water. The reagent is: *(2015 Re)*

a. Sodium hydrogen sulphite
b. A Grignard reagent
c. Hydrazine in presence of feebly acidic solution
d. Hydrocyanic acid

34. An organic compound 'X' having molecular formula $C_5H_{10}O$ yields phenyl hydrazone and gives negative response to the Iodoform test and Tollen's test. It produces n-pentane on reduction. 'X' could be: [MR*] *(2015)*

a. 2-pentanone
b. 3-pentanone
c. n-pentyl alcohol
d. Pentanal

35. The order of stability of the following tautomeric compounds is: [MR*] *(2013)*



a. II > I > III
b. II > III > I
c. I > II > III
d. III > II > I

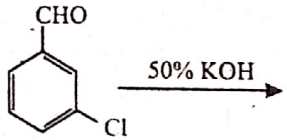
36. Which of the following compounds will give a yellow precipitate with iodine and alkali? *(2012 Mains)*

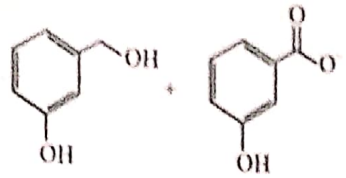
a. 2-Hydroxypropane
b. Acetophenone
c. Methyl acetate
d. Acetamide

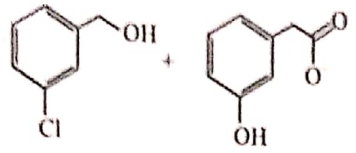
37. Consider the reaction:
$RCHO + NH_2NH_2 \rightarrow RCH = N - NH_2$
What sort of reaction is it? [MR*] *(2012 Mains)*

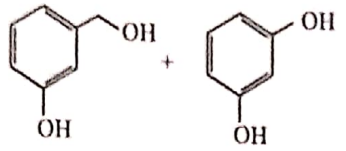
a. Nucleophilic addition + elimination reaction
b. Electrophilic addition + elimination reaction
c. Free radical addition + elimination reaction
d. Electrophilic substitution + elimination reaction

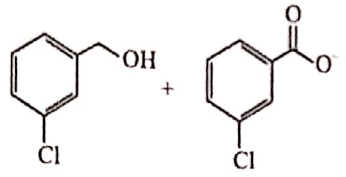
38. Predict the products in the given reaction: *(2012 Pre)*



a. 

b. 

c. 

d. 

39. CH_3CHO and $C_6H_5CH_2CHO$ can be distinguished chemically by: [MR*] *(2012 Pre)*

a. Fehling solution test b. Benedict test
c. Iodoform test d. Tollen's reagent test

40. Acetone is treated with excess of ethanol in the presence of hydrochloric acid. The product obtained is: *(2012 Pre)*

a. $CH_3CH_2CH_2-\overset{\overset{O}{\|}}{C}-CH_3$

b. $CH_3CH_2CH_2-\overset{\overset{O}{\|}}{C}-CH_2CH_2CH_3$

c. $(CH_3)_2C(OH)(OC_2H_5)$

d. $(CH_3)_2C(OC_2H_5)_2$

41. Clemmensen reduction of a ketone is carried out in the presence of which of the following? *(2011 Pre)*

a. H_2 and Pt as catalyst b. Glycol with KOH
c. Zn-Hg with HCl d. $LiAlH_4$

42. Following compounds are given: *(2010 Mains)*

A. CH_3CH_2OH B. CH_3COCH_3

C. $CH_3-CHOH-CH_3$ D. CH_3OH

Which of the above compound(s), on being warmed with iodine solution and NaOH, will give iodoform?

a. A, C and D b. Only B
c. A, B and C d. A and B

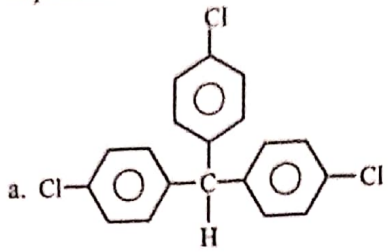
43. Among the given compounds, the most susceptible to nucleophilic attack at the carbonyl group is: *(2010 Pre)*

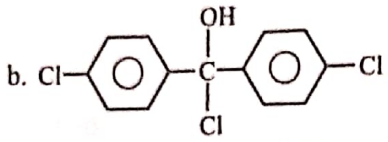
a. CH_3COCl b. CH_3COOCH_3
c. CH_3CONH_2 d. $CH_3COOCOCH_3$

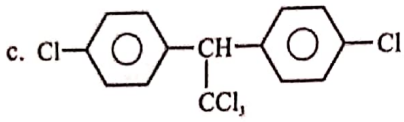
44. Which of the following reactions will not result in the formation of carbon-carbon bonds? *(2010 Pre)*

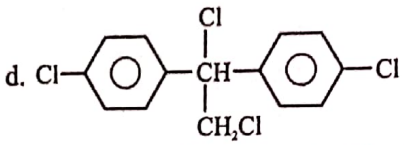
a. Friedel-Crafts acylation b. Reimer-Tieman reaction
c. Cannizzaro reaction d. Wurtz reaction

45. Trichloroacetaldehyde, CCl_3CHO reacts with chlorobenzene in presence of sulphuric acid produces: *(2009)*

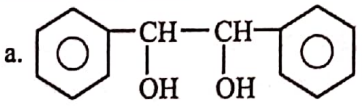
a. 

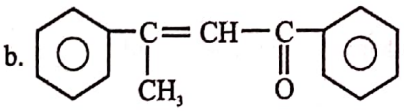
b. 

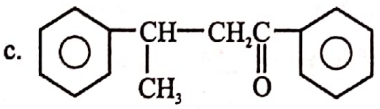
c. 

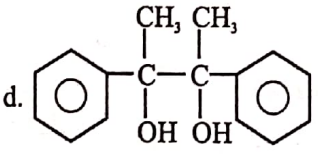
d. 

46. Acetophenone when reacted with a base, C_2H_5ONa, yields a stable compound which has the structure? [MR*] *(2008)*

a. 

b. 

c. 

d. 

47. A strong base can abstract an α-hydrogen from: *(2008)*

a. Alkane b. Alkene
c. Amine d. Ketone

48. Which one of the following on treatment with 50% aqueous sodium hydroxide yields the corresponding alcohol and acid? *(2007)*

a. C_6H_5CHO b. $CH_3CH_2CH_2CHO$

c. $CH_3-\overset{\overset{O}{\|}}{C}-CH_3$ d. $C_6H_5CH_2CHO$

49. Reduction of aldehydes and ketones into hydrocarbons using zinc amalgam and conc. HCl is called: *(2007)*

a. Cope reduction
b. Dow reduction
c. Wolf-Kishner reduction
d. Clemmensen reduction

50. The product formed in aldol condensation is: *(2007)*

a. A beta-hydroxy aldehyde or a beta-hydroxy ketone
b. An alpha-hydroxy aldehyde or ketone
c. An alpha, beta unsaturated ester
d. A beta-hydroxy acid

51. Nucleophilic addition reaction will be most favoured in: *(2006)*

a. $CH_3-CH_2-CH_2\overset{\overset{O}{\|}}{C}-CH_3$

b. $(CH_3)_2C=O$

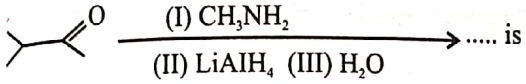
c. CH_3CH_2CHO

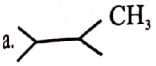
d. CH_3CHO

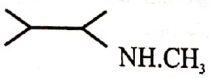
52. A carbonyl compound reacts with hydrogen cyanide to form cyanohydrin which on hydrolysis forms a racemic mixture of α-hydroxy acid. The carbonyl compound is: *(2006)*

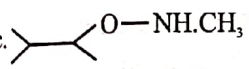
a. Acetaldehyde
b. Acetone
c. Diethyl ketone
d. Formaldehyde

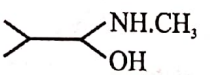
53. The major organic product formed from the following reaction: *(2005)*



a. 

b. 

c. 

d. 

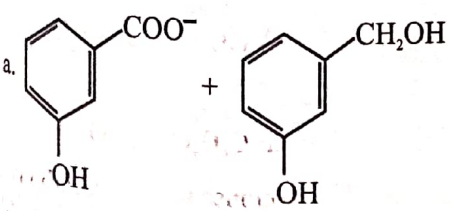
54. In this reaction :

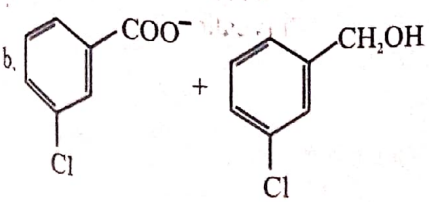
$$CH_3CHO + HCN \rightarrow CH_3CH(OH)CN \xrightarrow{HOH} CH_3CH(OH)COOH$$

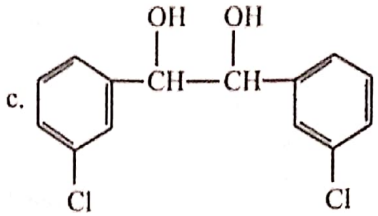
an asymmetric centre is generated. The acid obtained would be: **[MR*]** *(2003)*

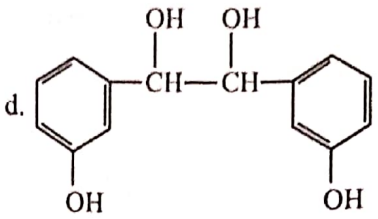
a. D-isomer
b. L-isomer
c. 50% D + 50% L-isomer
d. 20% D + 80% L-isomer

55. When m-chlorobenzaldehyde is treated with 50% KOH solution, the product(s) obtained is (are): **[MR*]** *(2003)*

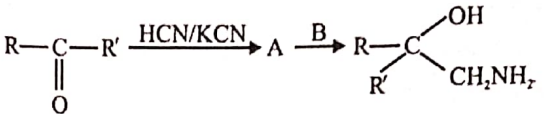
a. 

b. 

c. 

d. 

56. A and B in the following reaction are: *(2003)*



a. A = RR′ C(OH)(COOH), B = NH_3

b. A = RR′ C(CH)(OH), B = $H_3O^{\oplus}$

c. A = RR′ CH_2CN, B = NaOH

d. A = RR′ C(CN)(OH), B = $LiAlH_4$

57. $\overset{\ominus}{C}H_2-\overset{\overset{O}{\|}}{C}-CH_3$ and $CH_2=\underset{\underset{\ominus}{O}}{\overset{|}{C}}-CH_3$ are: **[MR*]** *(2002)*

a. Resonating structures
b. Tautomers
c. Geometrical isomers
d. Optical isomers

58. Polarization in acrolein as: *(2000)*

a. $\overset{+\delta}{C}H_2=\overset{-\delta}{C}H-CHO$
b. $\overset{-\delta}{C}H_2=CH-\overset{+\delta}{C}HO$
c. $\overset{-\delta}{C}H_2=CH-\overset{+\delta}{C}HO$
d. $\overset{+\delta}{C}H_2=CH-\overset{-\delta}{C}HO$

59. First product of the reaction between RCHO and NH_2NH_2: *(2000)*

a. $RCH=NNH_2$
b. RCH = NH
c. RCH_2NH_2
d. $RCON_3$

60. Aldol condensation will not take place in: *(1999)*

a. HCHO
b. CH_3CHO
c. CH_3COCH_3
d. CH_3CH_2CHO

61. Iodoform test is not given by: *(1998)*

a. 2-pentanone
b. Ethanal
c. Ethanol
d. 3-pentanone

62. An ester (A) with molecular formula $C_9H_{10}O_2$ was treated with excess of CH_3MgBr and the complex so formed was treated with H_2SO_4 to give an olefin (B). Ozonolysis of (B) gave a ketone with molecular formula C_8H_8O which shows positive idoform test. The structure of (A) is: **[MR*]** *(1998)*

a. $C_6H_5COOC_2H_5$
b. $C_6H_3COOC_6H_5$
c. $H_3COCH_2COC_6H_5$
d. p–H_3CO–C_6H_4–$COCH_3$

63. Phenylmethanol can be prepared by reducing the benzaldehyde with: *(1997)*

a. CH_3Br and Na
b. CH_3I and Mg
c. CH_3Br
d. Zn and HCl

64. The order of reactivity of carbonyl compounds for nucleophilic addition is: [MR$^{\Delta}$] *(1995)*

a. $Ar_2C=O > R_2C=O > ArCHO > RCHO > H_2C=O$
b. $H_2C=O > R_2C=O > Ar_2C=O > RCHO > ArCHO$
c. $H_2C=O > RCHO > ArCHO > R_2C=O > Ar_2C=O$
d. $ArCHO > Ar_2C=O > RCHO > R_2C=O > H_2C=O$

65. In the reaction $CH_3CHO + HCN \rightarrow CH_3CH(OH)CN$, a chiral centre is produced. This product is: *(1995)*

a. Dextrorotatory
b. Racemic mixture
c. Meso compound
d. Laevorotatory.

66. Compound *A* has a molecular formula C_2Cl_3OH. It reduces Fehling's solution and on oxidation it gives a monocarboxylic acid *B*. If *A* is obtained by the action of chlorine on ethyl alcohol, then compound *A* is: *(1994)*

a. Methyl chloride
b. Monochloroacetic acid
c. Chloral
d. Chloroform

67. Which of the following compound will undergo self aldol condensation in the presence of cold dilute alkali? *(1994)*

a. $CH \equiv C - CHO$
b. $CH_2 = CHCHO$
c. C_6H_5CHO
d. CH_3CH_2CHO

68. Which of the following compounds will give positive test with Tollen's reagent? *(1994)*

a. Acetic acid
b. Acetone
c. Acetamide
d. Acetaldehyde

69. $(CH_3)_2C=CHCOCH_3$ can be oxidized to $(CH_3)_2C=CHCOOH$ by: *(1993)*

a. Chromic acid
b. NaOI
c. Cu at 300°C
d. $KMnO_4$

70. In which of the following, the number of carbon atoms does not remain same when carboxylic acid is obtained by oxidation? *(1992)*

a. CH_3COCH_3
b. CCl_3CH_2CHO
c. $CH_3CH_2CH_2OH$
d. CH_3CH_2CHO

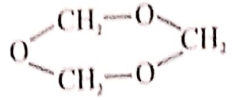
71. The reagent(s) which can be used to distinguish acetophenone from benzophenone is (are): *(1992)*

a. 2,4-dinitrophenylhydrazine
b. Aqueous solution of $NaHSO_3$
c. Benedict reagent
d. I_2 and NaOH.

72. Acetaldehyde reacts with: *(1991)*

a. Electrophiles only
b. Nucleophiles only
c. Free radicals only
d. Both electrophiles and nucleophiles.

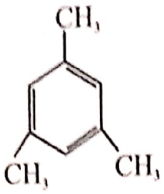
73.



The above shown polymer is obtained when a carbonyl compound is allowed to stand. It is a white solid. The polymer is: [OS] *(1989)*

a. Trioxane
b. Formose
c. Paraformaldehyde
d. Metaldehyde

74.



The given compound describes a condensation polymer which can be obtained in two ways : either treating 3 molecules of acetone (CH_3COCH_3) with conc. H_2SO_4 or passing propyne ($CH_3C \equiv CH$) through a red hot tube. The polymer is: [MR$^{\Delta}$] *(1989)*

a. Phorone
b. Mesityl oxide
c. Deacetonyl alcohol
d. Mesitylene

75. $3CH_3COCH_3 \xrightarrow[-3H_2O]{HCl}$

(A)

$(CH_3)_2C=CH-CO-CH=C(CH_3)_2$

(B)

This polymer (B) is obtained when acetone is saturated with hydrogen chloride gas, *B* can be: *(1989)*

a. Phorone
b. Formose
c. Diacetone alcohol
d. Mesityl oxide

76. If formaldehyde and KOH are heated, then we get: *(1988)*

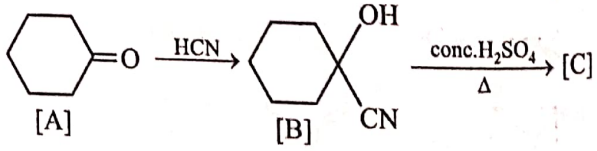
a. Methane
b. Methyl alcohol
c. Ethyl formate
d. Acetylene

77. Formalin is an aqueous solution of: *(1988)*

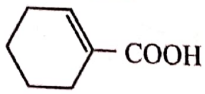
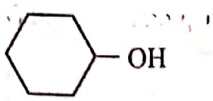
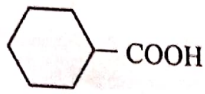
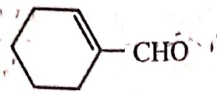
a. Fluorescein
b. Formic acid
c. Formaldehyde
d. Furfuraldehyde

Methods of Preparation of Carboxylic Acids

78. Complete the following reaction : *(2023)*



[C] is _____

a. 
b. 
c. 
d. 

79. $RMgX + CO_2 \xrightarrow[\text{ether}]{\text{dry}} Y \xrightarrow{H_3O^+} RCOOH$ *(2022)*

What is Y in the above reaction?

a. $(RCOO)_2Mg$ b. $RCOO^-Mg^+X$

c. $R_2CO^-Mg^+X$ d. $RCOO^-X^+$

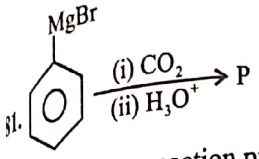
80. Consider the following reaction:

$$\text{Phenol} \xrightarrow{\text{Zn dust}} X \xrightarrow[\text{Anhydrous}]{CH_3Cl} Y \xrightarrow{\text{Alkaline } KMnO_4} Z$$

the product Z is: **[MR*]** *(2009)*

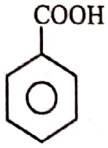
a. Benzaldehyde b. Benzoic acid

c. Benzene d. Toluene

81. 

In the above reaction product P is **[MR*]** *(2002)*

a.

b. 

c.

d.

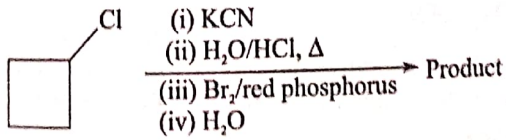
82. Which of the following compound gives benzoic acid on hydrolysis? *(1996)*

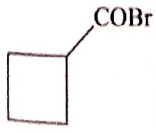
a. Chlorobenzene b. Benzoyl chloride

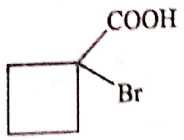
c. Chlorophenol d. Chlorotoluene

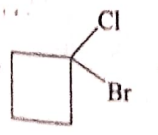
Physical Properties and Chemical Reactions of Carboxylic Acids

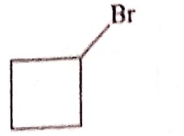
83. Identify the product in the following reaction **[MR*]** *(2023-Manipur)*



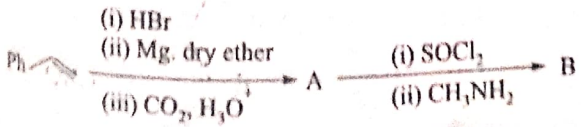
a. 

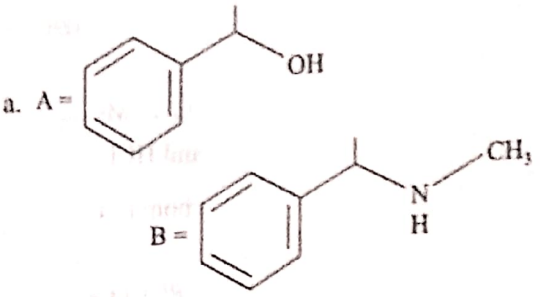
b. 

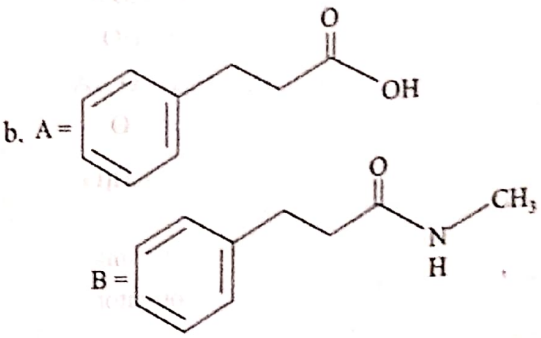
c. 

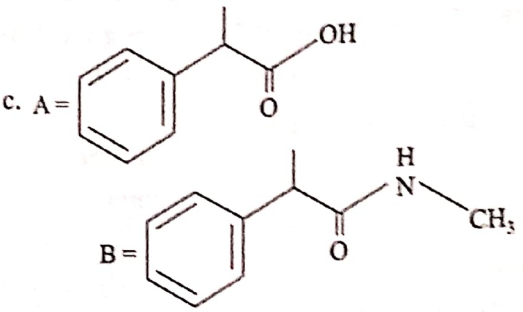
d. 

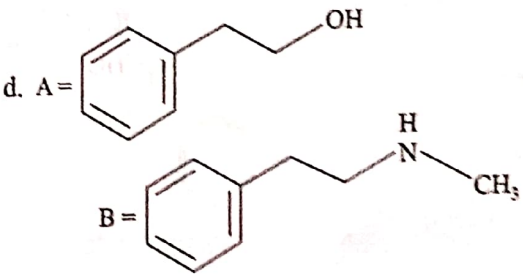
84. The products A and B in the following reaction sequence are: **[MR*]** *(2022 Re)*



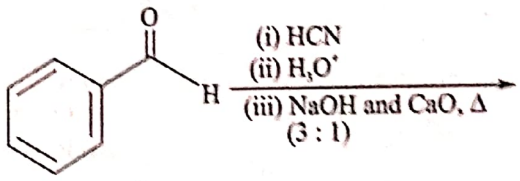
a. 

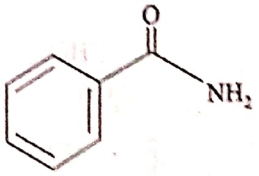
b. 

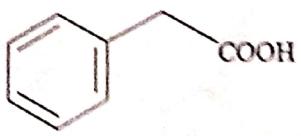
c. 

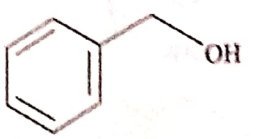
d. 

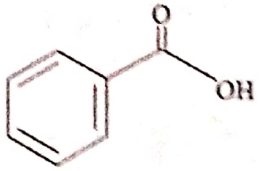
85. The product formed from the following reaction sequence is: *(2022 Re)*



a. 

b. 

c. 

d. 

86. $CH_3CH_2COO^-Na^+ \xrightarrow[\text{Heat}]{NaOH, +?} CH_3CH_3 + Na_2CO_3$.

Consider the above reaction and identify the missing reagent/ chemical. *(2021)*

a. Red Phosphorus b. CaO

c. DIBAL-H d. B_2H_6

Choose the correct answer from the options given below.

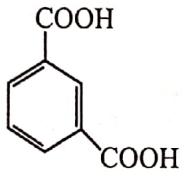
a. A-iii B-ii C-i D-iv

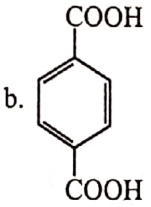
b. A-i B-iv C-iii D-ii

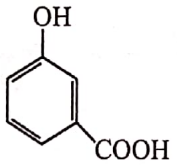
c. A-ii B-iii C-iv D-i

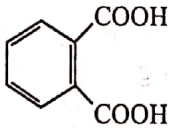
d. A-iv B-i C-ii D-iii

88. Which of the following acid will form an (i) Anhydride on heating and (ii) Acid imide on strong heating with ammonia? *(2020-Covid)*

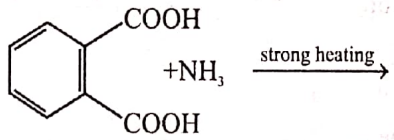
a. 

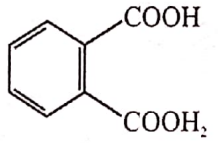
b. 

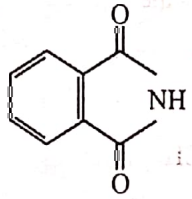
c. 

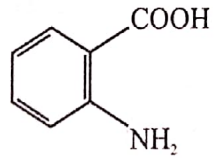
d. 

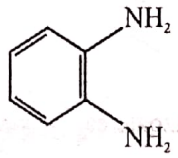
89. The major product of the following reaction is: *(2019)*



a. 

b. 

c. 

d. 

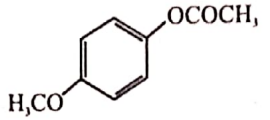
90. Carboxylic acids have higher boiling points than aldehydes, ketones and even alcohols of comparable molecular mass. It is due to their: *(2018)*

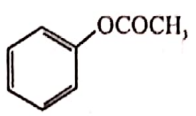
a. Formation of intramolecular H-bonding

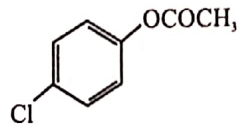
b. Formation of carboxylate ion

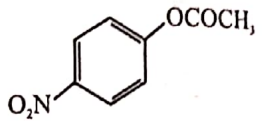
c. Benzaldehyde

93. Which one of the following esters gets hydrolysed most easily under alkaline conditions? *(2015 Re)*

a. 

b. 

c. 

d. 

94. The correct order of decreasing acid strength of trichloroacetic acid (A), trifluoroacetic acid (B), acetic acid (C) and formic acid (D) is **[MR*]** *(2012)*

a. B > A > D > C b. B > D > C > A

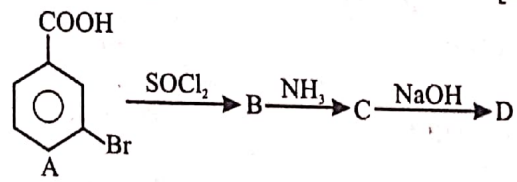
c. A > B > C > D d. A > C > B > D

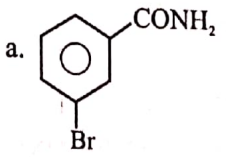
95. An organic compound 'A' on treatment with NH_3 gives 'B' which on heating gives 'C' when treated in presence of KOH produces ethylamine. Compound with Br in the 'A' is: **[MR*]** *(2011 Mains)*

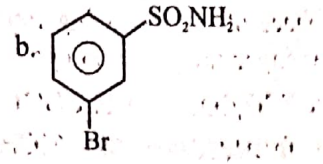
a. $CH_3-\underset{\displaystyle CH_3}{\overset{\displaystyle |}{CH}}-COOH$ b. CH_3CH_2COOH

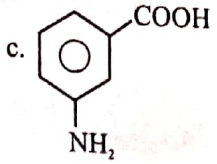
c. CH_3COOH d. $CH_3CH_2CH_2COOH$

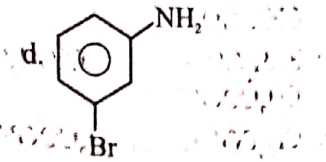
96. In a set of reactions m-bromobenzoic acid gave a product D. Identify the product D. **[MR*]** *(2011 Pre)*



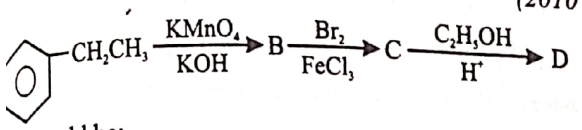
a. 

b. 

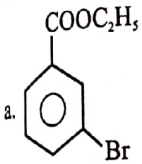
c. 

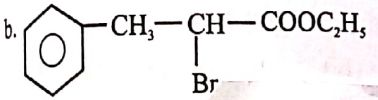
d. 

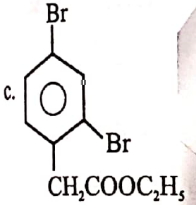
(2010 Pre)

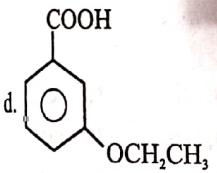


'D' would be:

a. 

b. 

c. 

d. 

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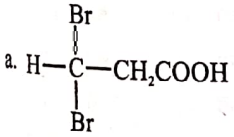
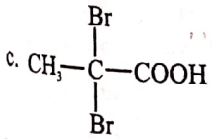
Propionic acid with Br_2/P yields a dibromo product. Its structure would be: *(2009)*

a. 

b. $CH_2(Br)—CH_2—COBr$

c. 

d. $CH_2(Br)—CH(Br)—COOH$

Which of the following represents the correct order of the acidity in the given compounds? *(2007)*

a. $FCH_2COOH > CH_3COOH > BrCH_2COOH > ClCH_2COOH$

b. $BrCH_2COOH > ClCH_2COOH > FCH_2COOH > CH_3COOH$

c. $FCH_2COOH > ClCH_2COOH > BrCH_2COOH > CH_3COOH$

d. $CH_3COOH > BrCH_2COOH > ClCH_2COOH > FCH_2COOH$

c. $CH_3CH_2NHCH_3$ d. $CH_3CH_2NH_2$

103. Self condensation of two moles of ethyl acetate in presence of sodium ethoxide yields: *(2006)*

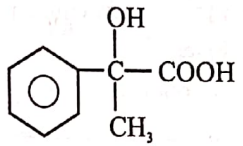
a. Ethyl propionate b. Ethyl butyrate

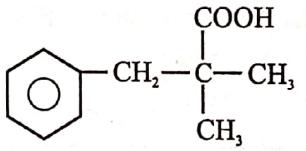
c. Acetoacetic ester d. Methyl acetoacetate

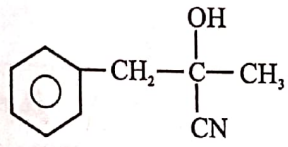
104. In a set of reactions, acetic acid yielded a product D.

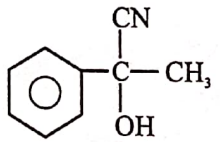
$$CH_3COOH \xrightarrow{SOCl_2} A \xrightarrow[\text{Anhyd. } AlCl_3]{\text{Benzene}} B \xrightarrow{HCN} C \xrightarrow{HOH} D$$

The structure of D would be: *(2005)*

a. 

b. 

c. 

d. 

105. The – OH group of an alcohol or the – COOH group of a carboxylic acid can be replaced by – Cl using: *(2004)*

a. Phosphorus pentachloride

b. Hypochlorous acid

c. Chlorine

d. Hydrochloric acid

106. In a set of the given reactions, acetic acid yielded a product C.

$$CH_3COOH + PCl_5 \rightarrow A \xrightarrow[\text{Anh., } AlCl_3]{C_6H_6} B \xrightarrow[\text{ether}]{C_2H_5MgBr} C$$

product C would be: **[MR*]** *(2003)*

a. $CH_3CH(OH)C_6H_5$ b. $CH_3COC_6H_5$

c. $CH_3CH(OH)C_6H_5$ d. $CH_3—C(OH)C_6H_5$ (with C_2H_5)

107. Ethyl benzoate can be prepared from benzoic acid by using: *(2000)*

a. Ethyl alcohol

b. Ethyl alcohol and dry HCl

c. Ethyl chloride

d. Sodium ethoxide

108. Reduction by $LiAlH_4$ of hydrolysed product of an ester gives: [MR*] *(2000)*

a. Two alcohols
b. Two aldehyde
c. One acid and one alcohol
d. Two acids

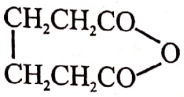
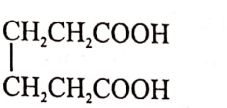
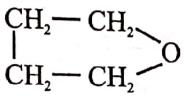
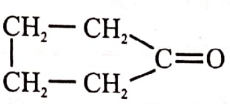
109. Which one of the following compounds will react with $NaHCO_3$ solution to give sodium salt and carbon dioxide? *(1999)*

a. Acetic acid
b. n-hexanol
c. Phenol
d. Both (b) and (c)

110. Which one of the following esters cannot undergo Claisen self-condensation? [MR*] *(1998)*

a. $CH_3CH_2CH_2COOC_2H_5$
b. $C_6H_5COOC_2H_5$
c. $C_6H_5CH_2COOC_2H_5$
d. $C_6H_{11}CH_2COOC_2H_5$

111. Which one of the following product is formed when adipic acid is heated? *(1995)*

a. 
b. 
c. 
d. 

112. An acetyl halide is formed when PCl_5 reacts with an: *(1994)*

a. Amide
b. Ester
c. Acid
d. Alcohol

113. Sodium formate on heating yields: *(1993)*

a. Oxalic acid and H_2
b. Sodium oxalate and H_2
c. CO_2 and NaOH
d. Sodium oxalate

114. Benzoic acid gives benzene on being heated with *X* and phenol gives benzene on being heated with *Y*. Therefore *X* and *Y* are respectively: *(1992)*

a. Soda-lime and copper
b. Zn dust and NaOH
c. Zn dust and soda-lime
d. Soda-lime and zinc dust.

115. The compound formed when malonic acid is heated with urea is: [OS] *(1989)*

a. Cinnamic acid
b. Butyric acid
c. Barbituric acid
d. Crotonic acid.

116. Among the following the strongest acid is: *(1988)*

a. CH_3COOH
b. CH_2ClCH_2COOH
c. $CH_2ClCOOH$
d. CH_3CH_2COOH

117. Which of the following is the correct decreasing order of acidic strength of: *(1988)*

(i) Methanoic acid
(ii) Ethanoic acid
(iii) Propanoic acid
(iv) Butanoic acid

a. (i) > (ii) > (iii) > (iv)
b. (ii) > (iii) > (iv) > (i)
c. (i) > (iv) > (iii) > (ii)
d. (iv) > (i) > (iii) > (ii)

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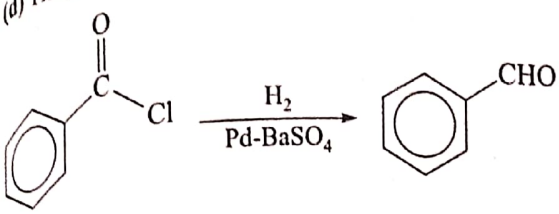
Answer Key

1. (d)	**2.** (a)	**3.** (d)	**4.** (b)	**5.** (d)	**6.** (d)	**7.** (b)	**8.** (d)	**9.** (c)	**10.** (b)
11. (a)	**12.** (c)	**13.** (d)	**14.** (a)	**15.** (a)	**16.** (c)	**17.** (b)	**18.** (d)	**19.** (b)	**20.** (d)
21. (a)	**22.** (b)	**23.** (b)	**24.** (a)	**25.** (c)	**26.** (c)	**27.** (c)	**28.** (d)	**29.** (b)	**30.** (b)
31. (c)	**32.** (b)	**33.** (c)	**34.** (b)	**35.** (d)	**36.** (b)	**37.** (a)	**38.** (d)	**39.** (c)	**40.** (d)
41. (c)	**42.** (c)	**43.** (a)	**44.** (c)	**45.** (c)	**46.** (b)	**47.** (d)	**48.** (a)	**49.** (d)	**50.** (a)
51. (d)	**52.** (a)	**53.** (b)	**54.** (c)	**55.** (b)	**56.** (d)	**57.** (a)	**58.** (d)	**59.** (a)	**60.** (a)
61. (d)	**62.** (a)	**63.** (d)	**64.** (c)	**65.** (b)	**66.** (c)	**67.** (d)	**68.** (d)	**69.** (b)	**70.** (a)
71. (d)	**72.** (b)	**73.** (a)	**74.** (d)	**75.** (a)	**76.** (b)	**77.** (c)	**78.** (a)	**79.** (b)	**80.** (b)
81. (b)	**82.** (b)	**83.** (b)	**84.** (c)	**85.** (c)	**86.** (b)	**87.** (c)	**88.** (d)	**89.** (b)	**90.** (c)
91. (d)	**92.** (a)	**93.** (d)	**94.** (a)	**95.** (b)	**96.** (d)	**97.** (d)	**98.** (a)	**99.** (c)	**100.** (c)
101. (c)	**102.** (d)	**103.** (c)	**104.** (a)	**105.** (a)	**106.** (d)	**107.** (b)	**108.** (a)	**109.** (a)	**110.** (b)
111. (a)	**112.** (c)	**113.** (b)	**114.** (d)	**115.** (c)	**116.** (c)	**117.** (a)			

Explanations

1. (d) The given reaction is Rosenmund reaction.



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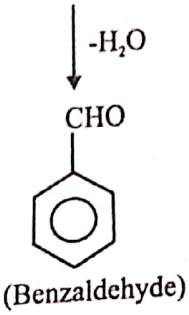
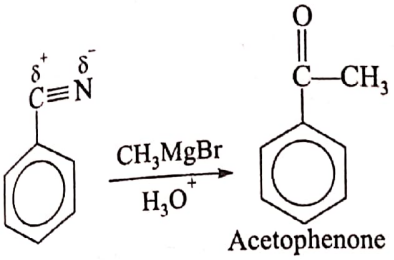
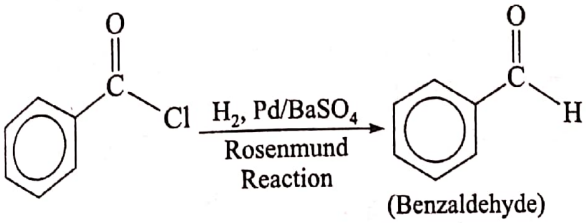


(Benzaldehyde)

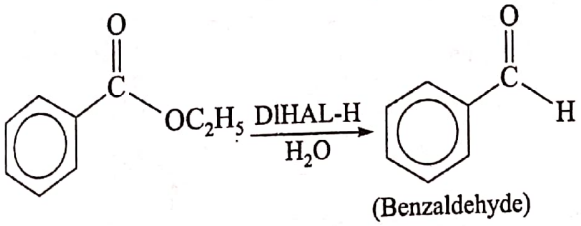
2. (a)

a. 

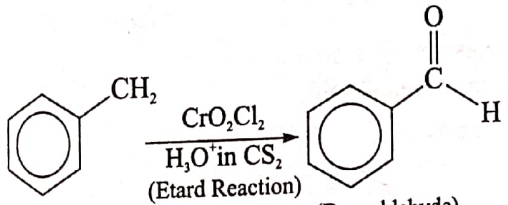
Acetophenone

b. 

(Benzaldehyde)

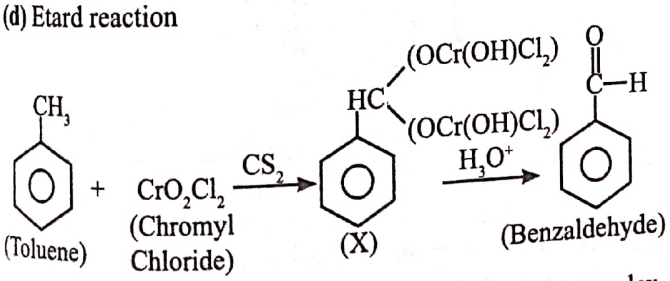
c. 

(Benzaldehyde)

d. 

(Benzaldehyde)

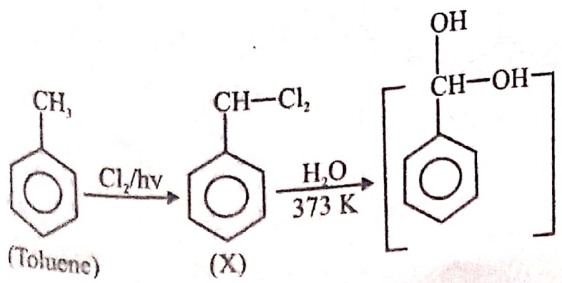
3. (d) Etard reaction



(Toluene) (Benzaldehyde)

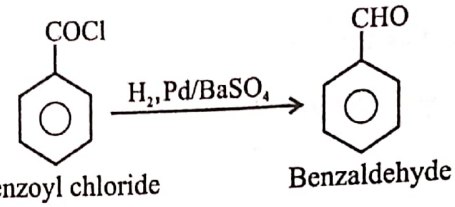
Chromyl chloride oxidises methyl group to a chromium complex, which on hydrolysis gives corresponding benzaldehyde.

4. (b)



(Toluene) (X)

5. **(d)** Rosenmund reaction



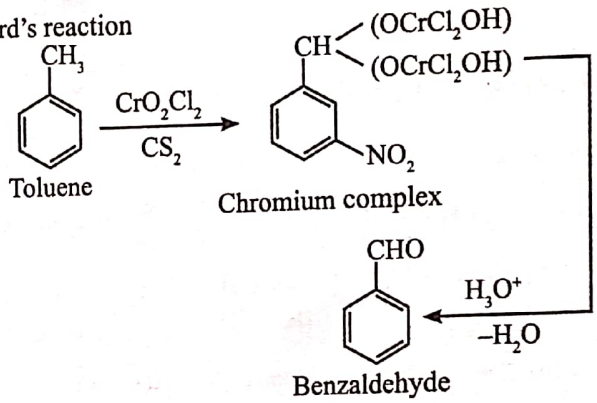
Benzoyl chloride Benzaldehyde

(A)

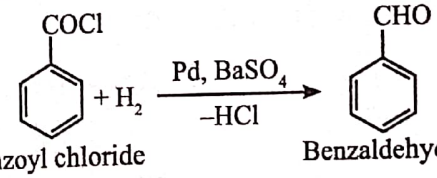
In Rosenmund reduction, acyl chloride (acid chloride) is hydrogenated over catalyst palladium on barium sulphate.

6. **(d)**

(a) Etard's reaction

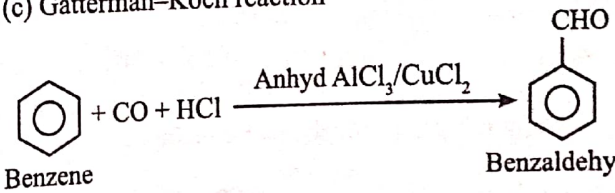


(b) Rosenmund reduction

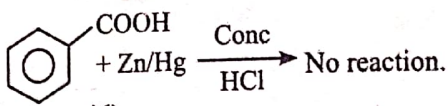


Benzoyl chloride Benzaldehyde

(c) Gatterman–Koch reaction



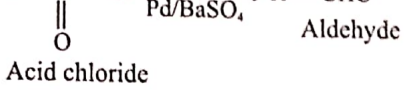
Benzene Benzaldehyde

(d) 

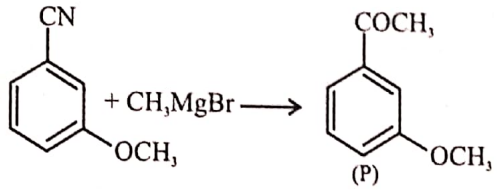
(Benzoic acid)

Reduction by the reagent Zn/Hg + conc. HCl is known as clemmensen reduction. It is used to reduce carbonyl group ($>C=O$) into ($>CH_2$) group.

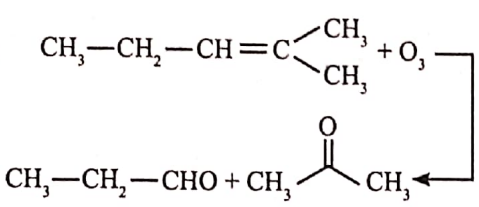
Reduction of carboxylic acid is not carried out by Zn/Hg + conc. HCl



10. (b)



11. (a) (a)



(b) $CH_3 — CH_2 — CH = CH — CH_2 — CH_3 + O_3 \longrightarrow 2CH_3 — CH_2 — CHO$

(c) $CH_3 — CH_2 — CH = CH — CH_3 + O_3 \longrightarrow CH_3 — CH_2 — CHO + CH_3 — CHO$

(d) $CH_3 — \underset{\displaystyle CH_3}{\overset{\displaystyle |}{C}} = CH — CH_2 + O_3 \longrightarrow CH_3 — \underset{\displaystyle CH_3}{\overset{\displaystyle |}{C}} = O + CH_3 — CHO$

12. (c) $CH_3CN + 2H \xrightarrow[SnCl_2]{HCl} CH_3 - CH = NH$

ethanitrile

$\downarrow H_2O$ boil

$CH_3 - CH = O + NH_3$

Acetaldehyde.

This reaction is called Stephen's Reduction.

13. (d) $CH \equiv CH + H_2O \xrightarrow[HgSO_4]{dil.H_2SO_4} CH_2 = CH — OH \rightleftharpoons CH_3 = \underset{\displaystyle O}{\overset{\displaystyle ||}{C}} — H$

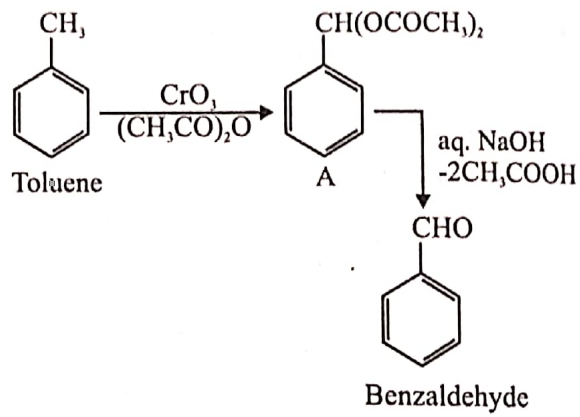
Acetylene

Acetaldehyde

14. (a) (a) $R — \underset{\displaystyle R}{\overset{\displaystyle |}{\underset{\displaystyle |}{C}}} — OH + [O] \xrightarrow{H^+} R — \underset{\displaystyle O}{\overset{\displaystyle ||}{C}} — R$

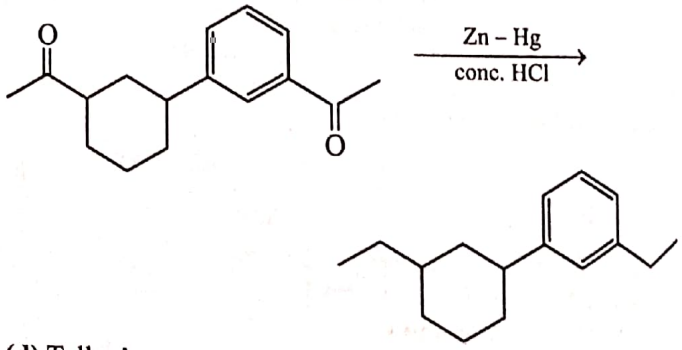
This reaction is called Etard's reaction.

16. (c)

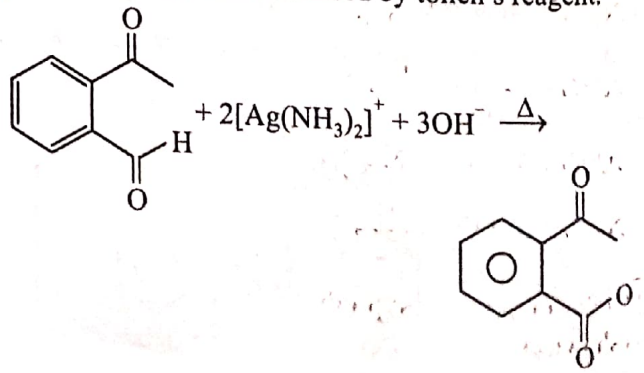


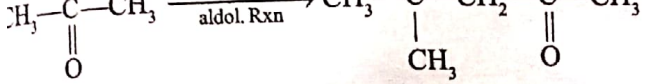
17. (b) Ketones are reduced into hydrocarbons using Zn-Hg/HCl (Clemmenson reduction).

$>C=O + Zn\text{-}Hg/HCl \rightarrow >CH_2$



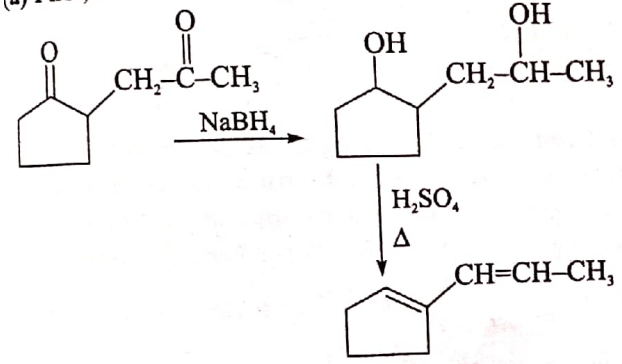
18. (d) Tollen's reagent oxidises aldehydes into carboxylate ion whereas ketone is not oxidised by tollen's reagent.





Functional groups present in product (X) are alcohol and ketone.

(a) First, reduction takes place followed by dehydration.



(b) In nucleophilic addition-elimination reactions, water molecule is eliminated along with the formation of product. But in reaction of CH_3CHO and $NaHSO_3$ only addition takes place. Hence, it is not an example of nucleophilic addition-elimination reactions.

. (b) Boiling point of comparable molecular mass compounds is given as,

R–OH	>	Aldehyde – Ketone	>	Alkane
H–bonding		Dipole-dipole interaction		Non-polar
(strong molecular association)		(weak molecular association)		

from the above given comparison it is clear that the boiling point of aldehydes and ketones are higher than hydrocarbons and lower than alcohols of the comparable molecular mass.

4. (a) $>C=O + HCN \xrightarrow{OH^{\ominus}} >C(OH)(CN)$ Cyanohydrin (Tautomerise)

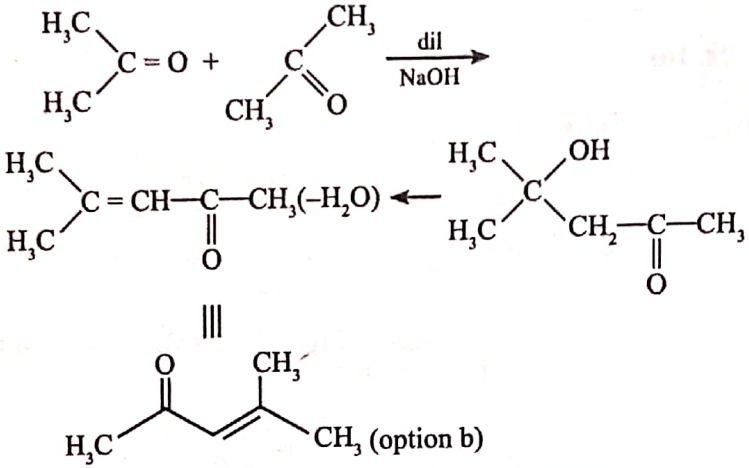
$>C=O + 2ROH \xrightarrow{H^+} R-CH(OR)-OR$ Acetal (Alcohol)

$>C=O + R-NH_2 \xrightarrow{H^+} >C=N-R$ Schiff's base

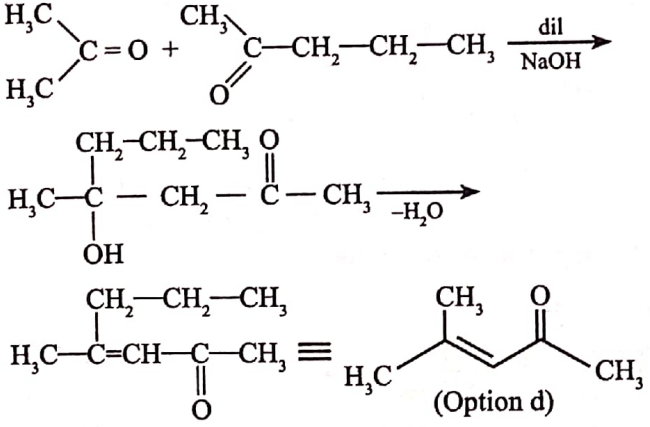
$>C=O + NH_2OH \xrightarrow{H^+} >C=N-OH$ Oxime

25. (c) Option (a) is the cross product of acetone and 2-pentanone. It is shown as-

Option b is the self aldol product of acetone. It is given as,

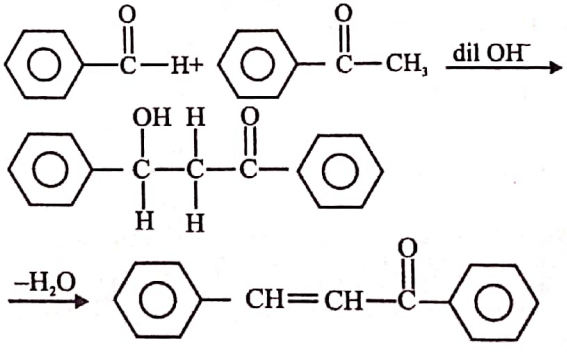


Option d is also a cross aldol product. It is given as-

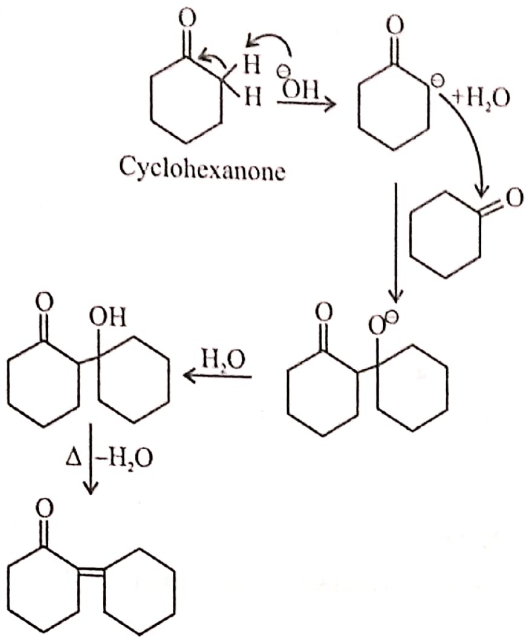


Option (c) is neither a cross aldol nor an aldol product of acetone and 2-pentanone.

26. (c) Reaction between benzaldehyde and acetophenone in presence of dilute NaOH is known as Cross Aldol condensation



27. (c)



28. (d)

$CH_3CH_2OH \xrightarrow[573K]{Cu} CH_3-\overset{O}{\overset{\|}{C}}-H$

(X) Ethanol (A) Acetaldehyde

$CH_3-\overset{O}{\overset{\|}{C}}-H + 2[Ag(NH_3)_2]OH \longrightarrow$

$2Ag\downarrow + CH_3-\overset{O}{\overset{\|}{C}}-O-\overset{+}{N}H_4 + 3NH_3 + H_2O$

(silver mirror)

$CH_3-\overset{O}{\overset{\|}{C}}-H \xrightarrow{-OH\ \Delta} CH_3-CH=CH-\overset{O}{\overset{\|}{C}}-H$ (Aldol condensation)

(A) Y But-2-enal

$CH_3-\overset{O}{\overset{\|}{C}}-H \xrightarrow{NH_2-NH-\overset{O}{\overset{\|}{C}}-NH_2}$

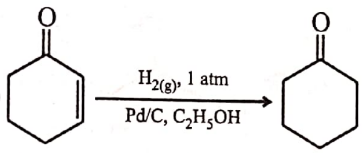
(A)

$CH_3-CH=N-NH-\overset{O}{\overset{\|}{C}}-NH_2$

(Z) Semicarbazone

∴ It is a substitution reaction.

29. (b)



C = C bond is reduced faster than C = O bond with H_2(Pd – C).

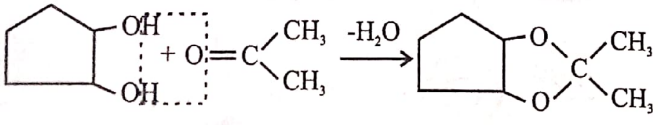
30. (b) Aldehyde + 1° amine ⟶ Schiff's base

$R-\overset{O}{\overset{\|}{C}}-H + R'-NH_2 \xrightarrow{-H_2O} R-\overset{H}{\overset{|}{C}}=NR'$

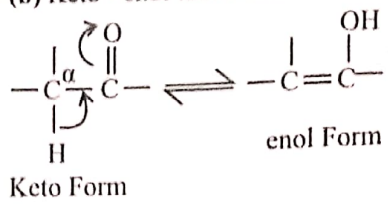
Aldehyde 1° amine

$\left[R-\overset{H}{\overset{|}{C}}=O + H_2N-R' \right] \xrightarrow{-H_2O}$ Schiff's base

31. (c) Trans isomer does not react with acetone.



32. (b) Keto - enol tautomerism:



33. (c)

(a) $>C=O$ (Carbonyl) $+ NaHSO_3 \longrightarrow >C<^{O^-Na^+}_{SO_3H}$ ⇌ (Proton Transfer) $>C<^{OH}_{SO_3Na}$ Sodium bisulphite adduct

(b) $>C=O + R\text{-}MgX \longrightarrow >C<^{O\ Mgx}_{R} \xrightarrow{H_3O^+} >C<^{OH}_{R}$

(c) $>C=O + H_2N-NH_2 \longrightarrow >C=N-NH_2 + H_2O$

Hydrazine Hydrozone

Removal of water take place.

(d) $>C=O + HCN \longrightarrow >C<^{OH}_{CN}$

Carbonyl Cyanohydrin

34. (b) A compound 'X' having molecular formula $C_5H_{10}O$ yields phenyl hydrozone means it must be carbonyl compound and give negative Tollen's test means compound must be Ketone and negative test for Iodoform means compound doesn't have $\left(CH_3-\overset{O}{\overset{\|}{C}}-\right)$ group. It produces n-pentane on reduction mean number of carbon atom in chain is 5.

$CH_3-CH_2-\overset{O}{\overset{\|}{C}}-CH_2-CH_3$

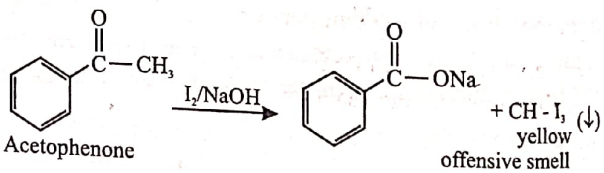
3-Pentanone will not give Iodoform test.

35. (d) $H_3C-\overset{O}{\overset{\|}{C}}-CH_2-\overset{O}{\overset{\|}{C}}-CH_3 \rightleftharpoons H_3C-\overset{O-H\cdots O}{\overset{|\quad\quad\|}{C=CH}}-C-CH_3$

Enol form

Stable due to intermolecular H-Bonding.

36. (b) Formation of yellow precipitate will take place when C_2H_5-OH or $CH_3-\overset{O}{\overset{\|}{C}}-$ group reacts with iodine & NaOH (alkali).



37. (a)

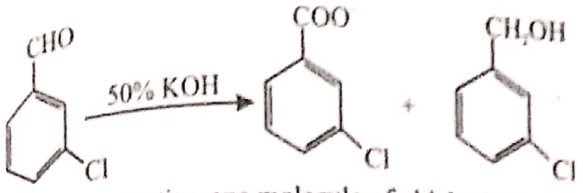
$R-\overset{O}{\overset{\|}{C}}-H + \ddot{H}_2N-NH_2 \underset{+H^+}{\overset{-H^+}{\rightleftharpoons}} R-\overset{OH\ H}{\overset{|\quad|}{C}}-N-NH_2$

Nucleophilic addition

Elimination

$\xrightarrow[\text{elimination}]{-H_2O}$

$R-CH=N-NH_2$

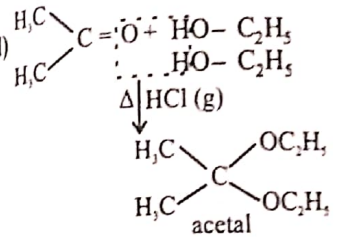
38. (d)


In Cannizzaro reaction one molecule of aldehyde is oxidised to a carboxylic salt & is reduced to alcohol.

39. (c) Aldehydes & ketones have $CH_3-\overset{O}{\overset{\|}{C}}$ group. These groups give a yellow colour ppt. & when boiled with iodine & NaOH (alkali) this is called iodoform reaction.

$$CH_3-\overset{O}{\overset{\|}{C}}-H + 4NaOH + 3I_2 \rightarrow \underset{\text{(Iodoform)}}{CHI_3} + HCOONa + 3NaI + 3H_2O$$

(Acetaldehyde)

40. (d)


41. (c) Clemmensen reduction of carboxyl compounds is an acid base reduction.

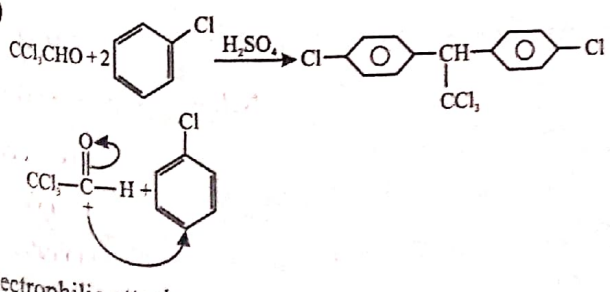
$$\text{>C=O} \xrightarrow[HCl]{Zn/Hg} \text{>CH}_2$$

42. (c) $CH_3CH_2OH, CH_3-\overset{O}{\overset{\|}{C}}-CH_3$ & $CH_3-\underset{CH_3}{\underset{|}{CH}}-OH$ will give iodoform reaction.

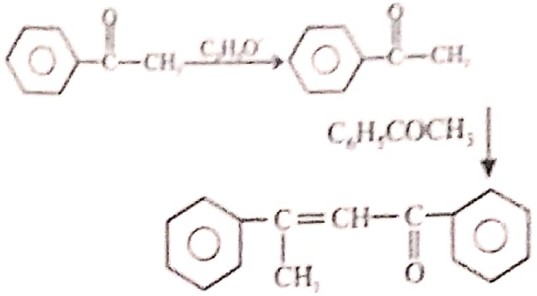
$-\overset{O}{\overset{\|}{C}}-CH_3$ & CH_3CH_2-OH like corresponds to iodoform reactions.

43. (a) For nucleophile to attack on a carboxyl atom, there should be a positive charge. Except CH_3–CO–Cl in all 3 options, the oxygen of the carboxyl group is resonance stabilized, so $CH_3-\overset{O}{\overset{\|}{C}}-Cl$ is most susceptible to nucleophilic attack. Also, Cl^- is a better leaving group.

44. (c) Cannizaro reactions (for compounds having no H at α - C) are disproportionate reactions which yields a carboxylic salt & alcohol.

45. (c)


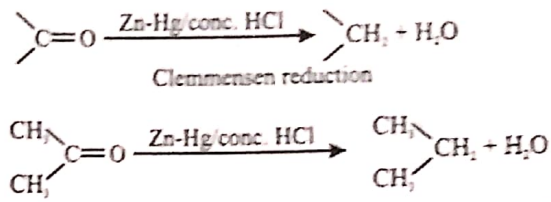
Electrophilic attack.

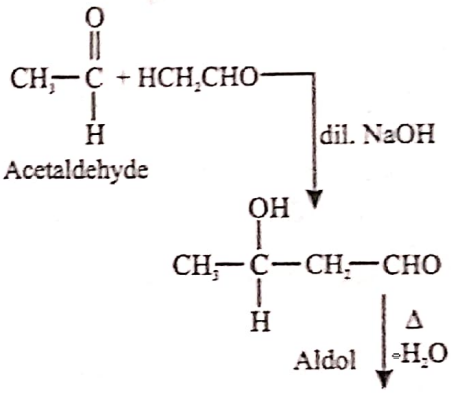
46. (b) Condensation reaction:


47. (d) α - H can be abstracted from a ketone as negativity on oxygen - increases because of +I of $-CH_3$ groups.

48. (a) Aldehydes containing no α-hydrogen atom on warming with 50% NaOH or KOH undergo disproportionation that is self oxidation - reduction known as Cannizzaro's reaction

$$2C_6H_5CHO + NaOH \xrightarrow{50\%\ NaOH} C_6H_5CH_2OH + C_6H_5COONa$$

49. (d)


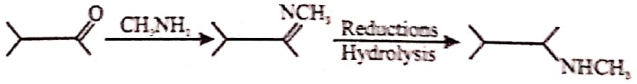
50. (a) Aldehydes and ketones having at least one α-hydrogen atom in presence of dilute alkali give β-hydroxy aldehyde or β-hydroxy ketone.


$CH_3-CH=CH.CHO$

(β-hydroxy aldehyde)

51. (d) CH_3CHO among 4 options, will favour nucleophilic reaction because of steric and electronic reasons. As less hinderance will be there for incoming reagent & +I effect of $-CH_3$ group increases positivity at carbonyl carbon.

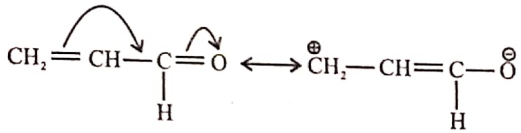
52. (a) Acetaldehyde undergoes such cyanohydrin formation (nucleophilic reaction) & forms α- hydroxy acid. Ketones are less reactive towards nucleophilic reaction because of steric & electronic reasons.

53. (b)


54. (c) Lactic acid [$CH_3CH(OH)COOH$] is an optically active compound due to the presence of asymmetric carbon atom. It exist in D and L-form the ratio of which is found to be (1:1), i.e., a racemic mixture.

resonating forms because the position of the atomic nuclei remain the same and only electron redistribution has occured.

58. **(d)** O-atom is more electronegative than C-atom, therefore O-atom bears partial negative charge and C-atom to which it is attached bear partial positive.

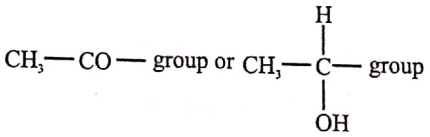


59. **(a)** It is a simple condensation reaction which proceeds with elimination of water.

$$R-CH=\boxed{O+H_2}N-NH_2 \xrightarrow{-H_2O} RCH=N-NH_2$$

60. **(a)** Aldol condensation in aldehyde is due to the presence of α-hydrogen atom. HCHO doesn't contain any α-Hydrogen.

61. **(d)** Iodoform test is given by compound which have



Hence, 2-pentanone, CH_3CHO and C_2H_5OH give this test and 3 - pentanone does not give iodoform test.

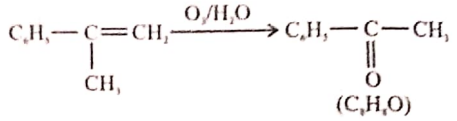
$$CH_3-COCH_2-CH_2-CH_3+3I_2+4NaOH$$
$$\longrightarrow \underset{\text{Iodoform}}{CHI_3}\downarrow +CH_3CH_2CH_2COONa$$
$$(\text{yellow ppt}) \quad +3NaI+3H_2O$$

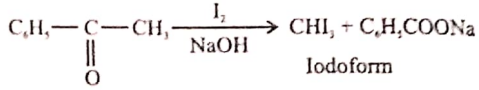
$$C_2H_5OH+4I_2+NaOH \rightarrow \underset{\text{Iodoform}}{CHI_3}\downarrow$$
$$(\text{yellow ppt.})$$
$$+HCOONa+5NaI+5H_2O$$

In the following reaction

$$CH_3-CHO \xrightarrow{I_2+NaOH} CHI_3+HCOONa$$
$$CH_3-CH_2-CO-CH_2-CH_3+I_2+NaOH \rightarrow \text{No reaction}$$

(B)



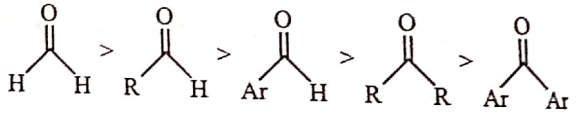


63. **(d)** $\underset{\text{Benzaldehyde}}{C_6H_5CHO}+2[H] \xrightarrow{Zn/HCl} \underset{\substack{\text{Phenylmethanol}\\(\text{Benzyl alcohol})}}{C_6H_5CH_2OH}$

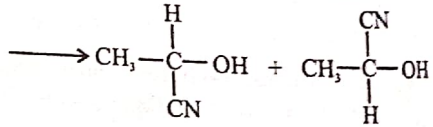
64. **(c)** Reactivity of aldehyde is more than the ketone in nucleophilic addition reactions due to steric and electronic reasons.

Aromatic aldehyde or ketones are less reactive than Aliphatic aldehydes or ketones because of greater delocalization of positive charge on the electrophilic carbon due to resonance.

So, order of reactivity is:



65. **(b)** $CH_3-CH=O+HCN \longrightarrow CH_3-\underset{\ominus}{\overset{\oplus}{CH=OH}}\quad \overset{\ominus}{CN}$



(Racemic mixture)

66. **(c)** $\underset{\text{(Ethylalcohol)}}{CH_3CH_2OH} \xrightarrow[-2HCl]{Cl_2} \underset{\text{(Acetaldehyde)}}{CH_3CHO} \xrightarrow[-3HCl]{3Cl_2} CCl_3CHO.$

(Chloral)

Thus, the compound *A* is chloral.

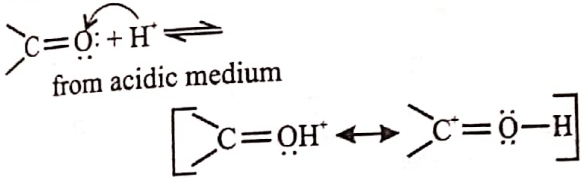
67. **(d)** CH_3CH_2CHO has α-hydrogen atom, so it will undergo aldol condensation in the presence of cold dilute alkali.

71. (d) Aceto... ppt. of CHI_3 but benzophenone ($C_6H_5COC_6H_5$) does not. Hence, it can be used to distinguish between them.

$$C_6H_5COCH_3 \xrightarrow{I_2,\ NaOH} CHI_3 + C_6H_5COONa$$

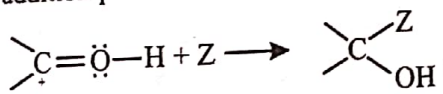
Yellow ppt.

72. (b) Acetaldehyde reacts only with nucleophiles. Since the mobile π-electrons of carbon oxygen double bond are strongly pulled towards oxygen, carbonyl carbon is electron-deficient and carbonyl oxygen is electron-rich. Thus, the electron deficient carbonyl carbon is most susceptible to attack by electron rich nucleophilic reagent, *i.e.*, by base.

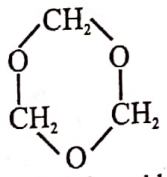


from acidic medium

The nucleophile, then attacks the protonated carbonyl group to form addition product.

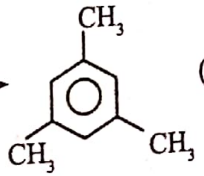


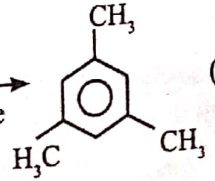
Nucleophile Addition product

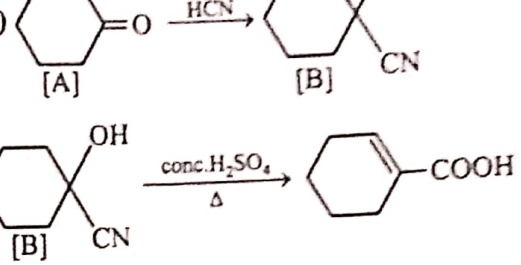
73. (a) $3HCHO \underset{\text{aq. soln.}}{\rightleftharpoons}$ 

Trioxane (metaformaldehyde)

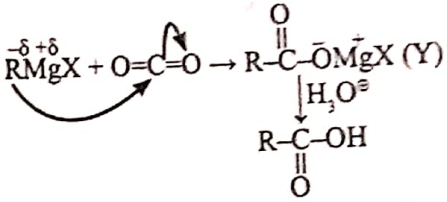
74. (d)

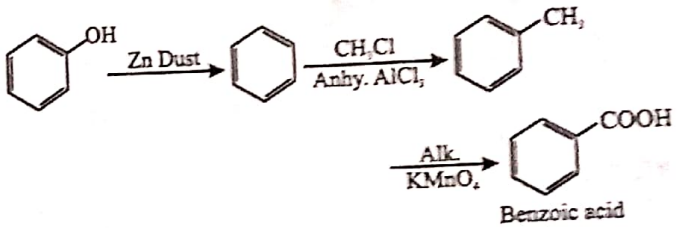
(i) $3CH_3-CO-CH_3 \xrightarrow[H_2SO_4]{\text{conc.}}$  (mesitylene)

(ii) $3CH_3-C\equiv CH \xrightarrow[\text{Metal tube}]{\text{Red hot}}$  (mesitylene)

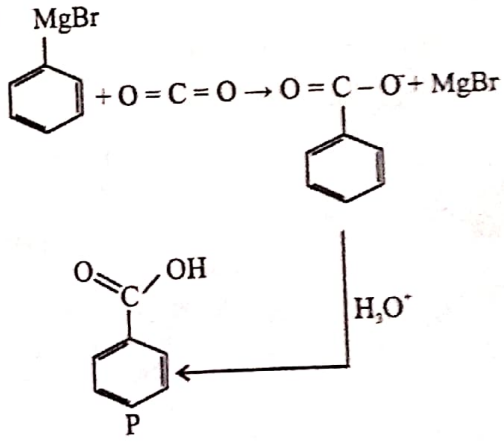
78. (a) 

79. (b) RMgX is a Grignard reagent and it is used to prepare carboxylic acid. The suitable reaction is given as-



80. (b) 

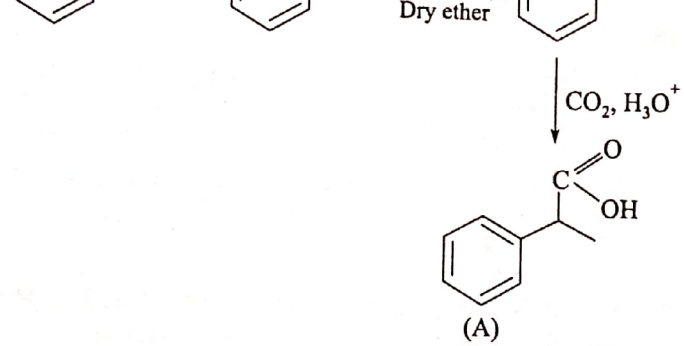
Benzoic acid

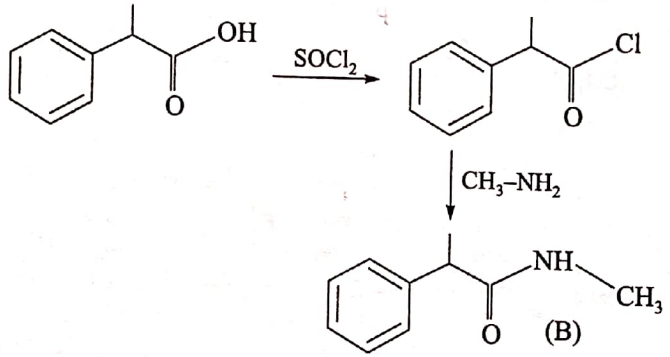
81. (b) 

82. (b) $C_6H_5COCl + H_2O \rightarrow C_6H_5COOH + HCl$

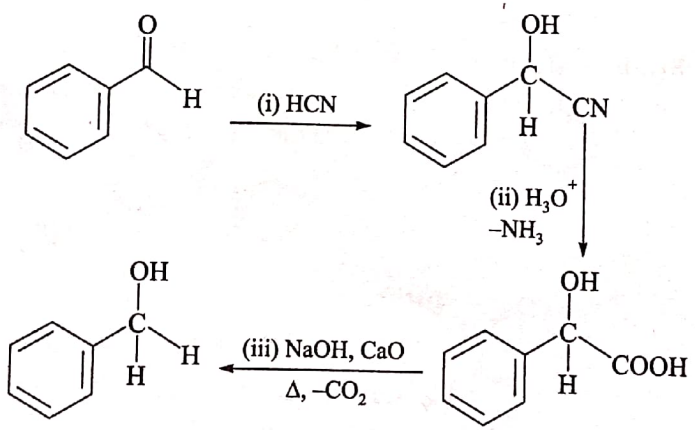
Benzoyl chloride Benzoic acid

while in case of their chlorine group is substituted by hydrogen.





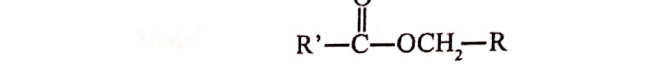
85. (c)



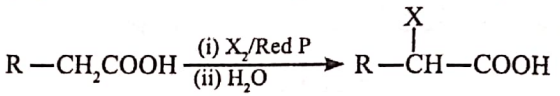
86. (b) When, sodium salt of carboxylic acid is heated with sodalime (NaOH and CaO), it produces alkane.

$$CH_3CH_2COO^-Na^+ \xrightarrow[\text{Heat}]{\text{NaOH+CaO}} CH_3CH_3 + Na_2CO_3$$

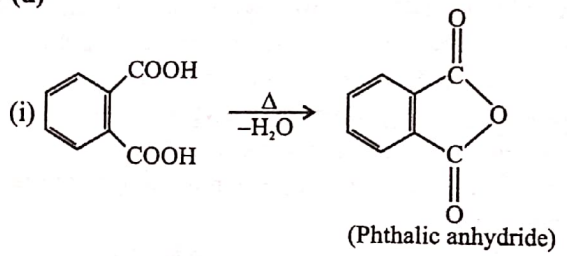
This reaction is known as decarboxylation reaction.

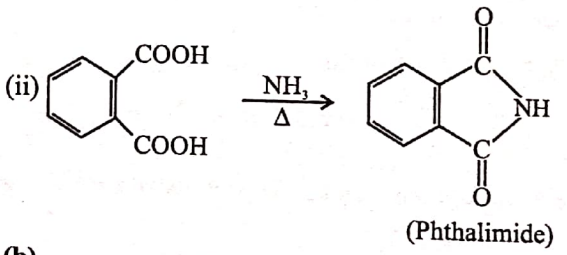


(D) Hell-Volhard-Zelinsky reaction: (HVZ)

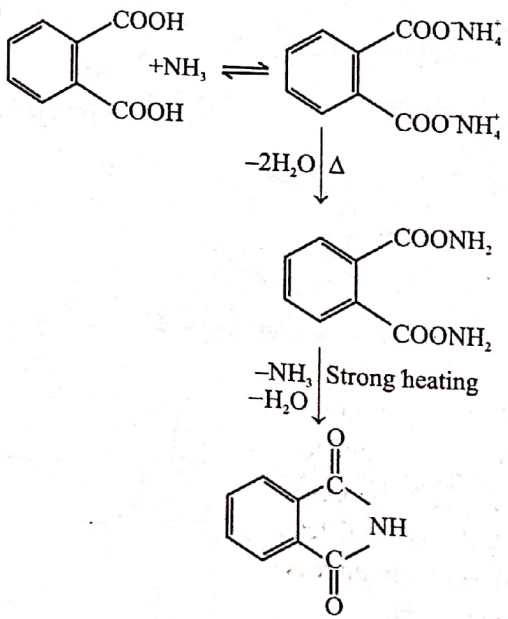


88. (d)





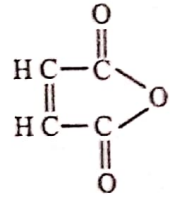
89. (b)



90. (c) Carboxylic acids have higher boiling points than aldehyde and Ketones and even alcohols of comparable mass due t Intermolecular H-bonding present in carboxylic acids.

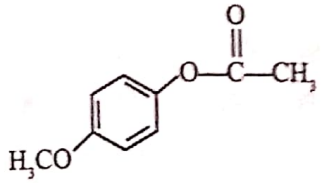
Maleic acid

Maleic anhydride



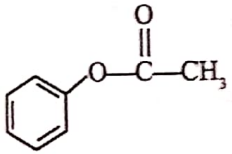
V_2O_5 oxidises benzene ring to maleic acid.

93. (d) (a)

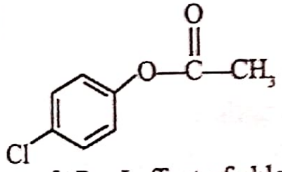


[+M effect of —OCH_3 group]

(b)

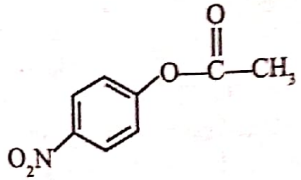


(c)



[+R, –I effect of chlorine group
– I dominating in case of Halogen)

(d)



[–M, – I effect of —NO_2 group]

As the electronegativity increases. More the nitro group with draw electrons towards itself more will be the acidity.

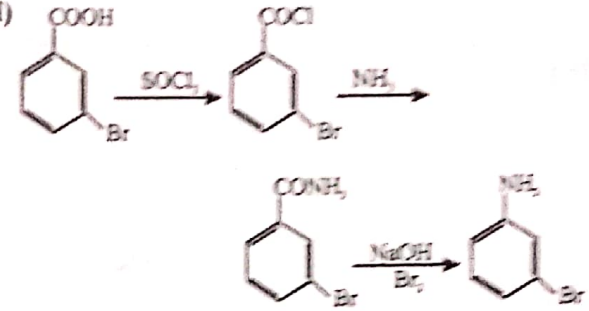
94. (a) As –I effect increases, –COOH group becomes more electron deficient and tendency to loose H^+ ions increases i.e., acid strength increases. As +I effect increases, acid strength decreases.

Thus, correct order of acid strength is

$$\underset{(B)}{CF_3COOH} > \underset{(A)}{CCl_3COOH} > \underset{(D)}{HCOOH} > \underset{(C)}{CH_3COOH}$$

degradation reaction.

96. (d)



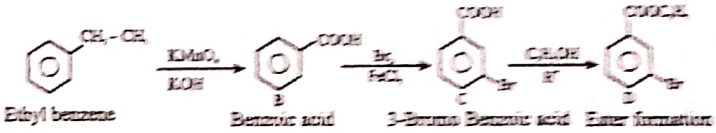
97. (d) Benzaldehyde - Benzoin condensation

Phthalic anhydride - Phenolphthalein

Phenyl benzoate - Fries rearrangement

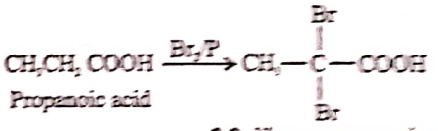
Methyl salicylate - Oil of wintergreen

98. (a)



Ethyl benzene — Benzoic acid — 3-Bromo Benzoic acid — Ester formation

99. (c) This is Hell - Volhard Zelinsky reaction.



Propanoic acid — 2,2-dibromopropanoic acid

100. (c) Electron withdrawing element increases the acidity by increasing the ionic character of –O–H by inductive effect. Electronegativity decreases in the order.

$$F > Cl > Br$$

Hence –I effect also decreases in the same order, therefore the correct option is:

$$FCH_2COOH > ClCH_2COOH > BrCH_2COOH > CH_3COOH$$

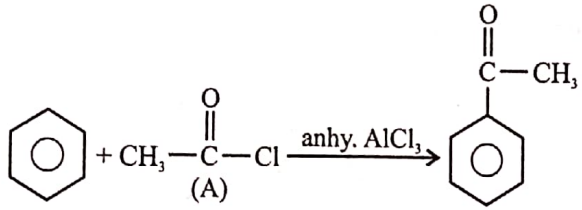
101. (c) The degree of hydrolysis increases as the magnitude of positive charge on carbonyl group increases. Electron withdrawing group increases the positive charge and electron releasing group decreases the negative charge. Among these, NO_2 & CHO are electron withdrawing group from which NO_2 has more –I effect than –CHO. On the other hand, CH_3 is a electron releasing group therefore, the order of reactivity towards hydrolysis becomes-

(c) Ethyl acetate undergoes claisen condensation in presence of sodium ethoxide involving α-H atom in which two molecules of ethyl acetate combine together to form acetoacetic ester.

$$H_3CCOOC_2H_5 + CH_3COOC_2H_5 \xrightarrow[\downarrow C_2H_5ONa]{} CH_3COCH_2COOC_2H_5 + C_2H_5OH$$

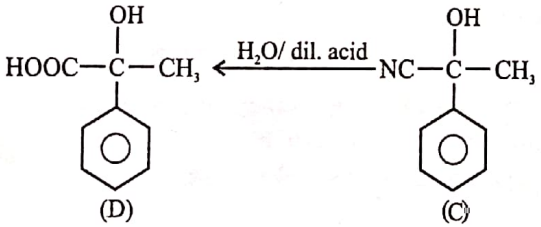
Acetoacetic ester

104. (a) $CH_3-COOH \xrightarrow{SOCl_2} CH_3-\overset{\overset{O}{\|}}{C}-Cl + SO_2\uparrow$ (A)



Friedel–Crafts acylation

Acetophenone (B)

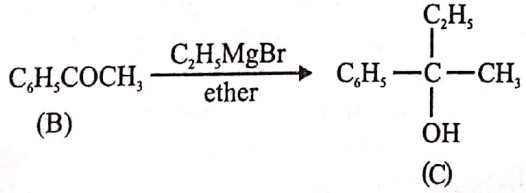


(D) (C)

105. (a) $ROH + PCl_5 \rightarrow RCl + POCl_3 + HCl$

$RCOOH + PCl_5 \rightarrow RCOCl + POCl_3 + HCl$

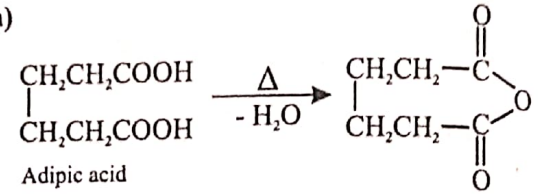
106. (d) $CH_3COOH + PCl_5 \rightarrow \underset{(A)}{CH_3COCl} \xrightarrow[\text{anhy. } AlCl_3]{C_6H_6}$ Friedel Craft's Acylation



(B) (C)

has no α-hydrogen atom or active methylene group so, it cannot undergo Claisen-Condensation reaction.

111. (a)



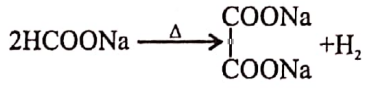
Adipic acid

Removal of water will take place.

112. (c) $3CH_3COOH + PCl_5 \rightarrow 3CH_3COCl + POCl_3 + HCl$

Acetic acid Acyl chloride

113. (b)



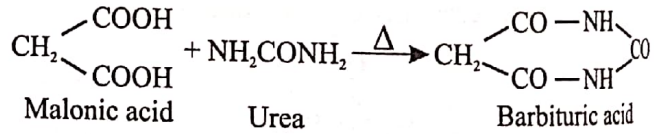
Sodium formate Sodium oxalate

114. (d) $C_6H_5COOH \xrightarrow[(X)]{\text{Soda-lime}} C_6H_6 + Na_2CO_3$

$C_6H_5OH \xrightarrow[(Y)]{\text{Zn dust}} C_6H_6 + ZnO$

X = soda-lime and Y = Zn dust

115. (c)



Malonic acid Urea Barbituric acid

116. (c) Strongest acid is $CH_2ClCOOH$. –I effect of Cl atom decreases with the increase in distance therefore, $CH_2ClCOOH$ is strongest acid.

117. (a) +I effect of the alkyl group increases from CH_3 to CH_3CH_2 to $CH_3CH_2CH_2$, resulting in the acid character to decrease. So, the order is (i) > (ii) > (iii) > (iv).

1. Which of the following reactions will NOT give primary amine as the product? [MR*] *(2023)*

a. $CH_3CONH_2 \xrightarrow[(ii)\ H_3O^{\oplus}]{(i)\ LiAlH_4}$ Product

b. $CH_3CONH_2 \xrightarrow{Br_2/KOH}$ Product

c. $CH_3CN \xrightarrow[(ii)\ H_3O^{\oplus}]{(i)\ LiAlH_4}$ Product

d. $CH_3NC \xrightarrow[(ii)\ H_3O^{\oplus}]{(i)\ LiAlH_4}$ Product

2. Match List - I with List – II: *(2022 Re)*

	List-I (Reaction)		List-II (Product formed)
A.	Gabriel synthesis	I.	Benzaldehyde
B.	Kolbe synthesis	II.	Ethers
C.	Williamson synthesis	III.	Primary amines
D.	Etard reaction	IV.	Salicylic acid

Choose the correct answer from the options given below

a. A-III, B-IV, C-II, D-I

b. A-III, B-I, C-II, D-IV

c. A-II, B-III, C-I, D-IV

d. A-IV, B-III, C-I, D-II

3. Reaction of propanamide with ethanolic sodium hydroxide and bromine will give *(2020-Covid)*

a. Methylamine b. Propylamine

c. Aniline d. Ethylamine

4. Method by which Aniline cannot be prepared is: [MR*] *(2015 Re)*

a. Potassium salt of phthalimide treated with chlorobenzene followed by hydrolysis with aqueous NaOH solution

b. Hydrolysis of phenylisocyanide with acidic solution

c. Degradation of benzamide with bromine in alkaline solution

d. Reduction of nitrobenzene with H_2/Pd in ethanol

c. Soda lime d. Hot conc. H_2SO_4

6. Which one of the following on reduction with lithium aluminium hydride yields a secondary amine? *(2007)*

a. Methyl isocyanide b. Acetamide

c. Methyl cyanide d. Nitroethane

7. Intermediates formed during reaction of $R-\underset{\underset{O}{\|}}{C}-NH_2$ with Br_2 and KOH are: [MR*] *(2001)*

a. RCONHBr and RNCO

b. RNHCOBr and RNCO

c. RNH - Br and RCONHBr

d. $RCONBr_2$

8. Amides can be converted into amines by reaction named after: *(1999)*

a. Perkin b. Claisen

c. Hoffmann d. Kekule

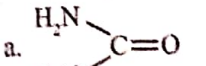
9. Indicate which nitrogen compound amongst the following would undergo Hoffmann reaction (*i.e.*..., reaction with Br_2 and strong KOH) to furnish the primary amine (R-NH_2)? *(1989)*

a. $RCONHCH_3$ b. $RCOONH_4$

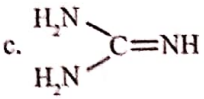
c. $RCONH_2$ d. $R-CO-NHOH$

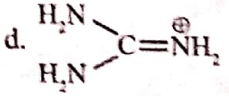
Physical & Chemical Properties of Amines

10. Which amongst the following compound/species is least basic? *(2023-Manipur)*

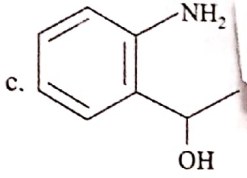
a. 

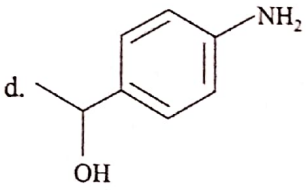
b.

c. 

d. 

TgI'd - @kohinoorofficial1

c. 

d. 

12. Given below are two statements: *(2022)*

Statements-I: Primary aliphatic amines react with HNO_2 to give unstable diazonium salts.

Statements-II: Primary aromatic amines react with HNO_2 to form diazonium salts which are stable even above 300 K.

In the light of the above Statements, choose the **most appropriate** answer from the options given below:

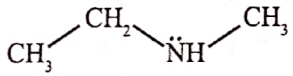
a. Statements-I is incorrect but Statements-II is correct.

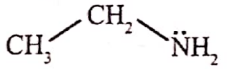
b. Both Statements-I and Statements-II are correct

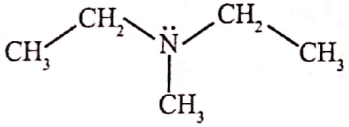
c. Both Statements-I and Statements-II are incorrect.

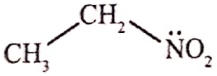
d. Statements-I is correct but Statement-II is incorrect.

13. Identify the compound that will react with Hinsberg's reagent to give a solid which dissolves in alkali. **[MR*]** *(2021)*

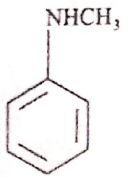
a. 

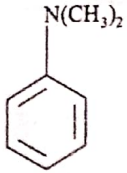
b. 

c. 

d. 

14. Which of the following amine will give the carbylamine test? *(2020)*

a. 

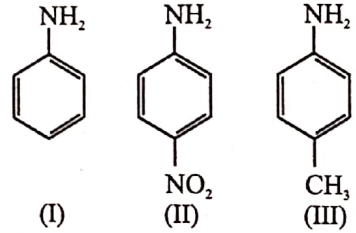
b. 

b. In electrophilic substitution reactions, amino group is meta directive.

c. In acidic (strong) medium, aniline is present as anilinium ion.

d. In absence of substituents nitro group always goes to m-position.

17. The correct increasing order of basic strength for the following compounds is: *(2017-Delhi)*



(I) (II) (III)

a. II < I < III

b. II < III < I

c. III < I < II

d. III < II < I

18. The correct statement regarding the basicity of arylamines is: *(2016 - I)*

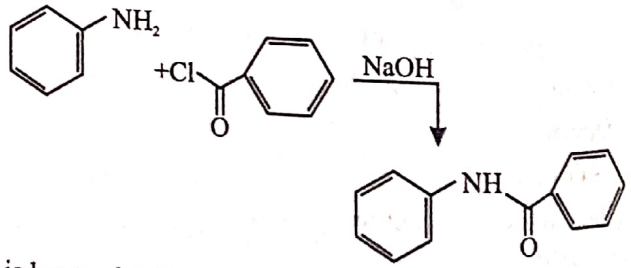
a. Arylamines are generally more basic than alkylamines, because the nitrogen atom in arylamines is sp-hybridised.

b. Arylamines are generally less basic than alkylamines because the nitrogen lone pair electrons are delocalized by interaction with the aromatic ring π.electrons system.

c. Arylamines are generally more basic than alkylamines because the nitrogen lone pair electrons are not delocalised by interaction with the aromatic ring π electron system.

d. Arylamines are generally more basic than alkylamines because of aryl group

19. The following reaction



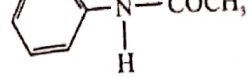
is known by the name: **[OS]** *(2015 Re)*

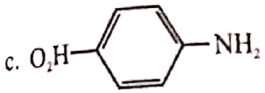
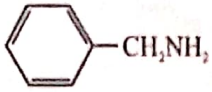
a. Schotten-Baumen reaction

b. Friedel-Craft's reaction

c. Perkin's reaction

d. Acetylation reaction

a. 

c.  d. 

22. Match the compounds given in List-I with their characteristic reactions given in List-II. Select the correct option: *(2010 Mains)*

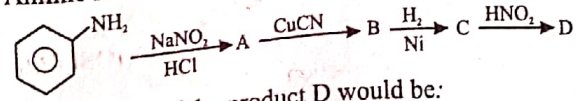
	List-I (Compounds)		List-II (Reactions)
A.	$CH_3CH_2CH_2CH_2NH_2$	(i)	Alkaline hydrolysis
B.	$CH_3C{\equiv}CH$	(ii)	With KOH (alcohol) and $CHCl_3$ produces bad smell
C.	$CH_3CH_2COOCH_3$	(iii)	Gives white ppt. with ammoniacal $AgNO_3$
D.	$CH_3CH(OH)CH_3$	(iv)	With Lucas reagent cloudiness appears after 5 minutes

a. A (ii), B (i), C (iv), D (iii)
b. A (iii), B (ii), C (i), D (iv)
c. A (ii), B (iii), C (i), D (iv)
d. A (iv), B (ii), C (iii), D (i)

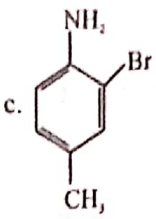
23. Which of the following statements about primary amines is 'False'? **[MR*]** *(2010 Pre)*
a. Alkyl amines are stronger bases than ammonia
b. Alkyl amines are stronger bases than aryl amines
c. Alkyl amines react with nitrous acid to produce alcohols
d. Aryl amines react with nitrous acid to produce phenols

24. Which of the following is more basic than aniline? *(2006)*
a. Diphenylamine b. Triphenylamine
c. p-nitroaniline d. Benzylamine

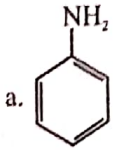
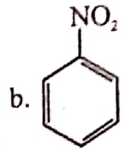
25. Aniline in a set of reactions yielded a product D.

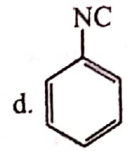


The structure of the product D would be: *(2005)*
a. $C_6H_5CH_2NH_2$ b. $C_6H_5NHCH_2CH_3$
c. C_6H_5NHOH d. $C_6H_5CH_2OH$

c.  d.

27. A $\xrightarrow{\text{reduction}}$ B $\xrightarrow{CHCl_3/KOH}$ C $\xrightarrow{\text{reduction}}$ N-methyl aniline; then A is: *(2000)*

a.  b. 

c. CH_3NH_2 d. 

28. Phenyl isocyanides are prepared from which of the following reaction? *(1999)*
a. Rosenmund's reaction
b. Carbylamine reaction
c. Reimer-Tiemann reaction
d. Wurtz reaction

29. Aniline is reacted with bromine water and the resulting product is treated with an aqueous solution of sodium nitrite in presence of dilute hydrochloric acid. The compound so formed is converted to a tetrafluoroborate which is subsequently heated. The final product is: **[MR*]** *(1998)*
a. 1, 3, 5-tribromobenzene
b. p-bromofluorobenzene
c. p-bromoaniline
d. 2, 4, 6-tribromofluorobenzene

30. The compound obtained by heating a mixture of ethyl amine and chloroform with ethanolic potassium hydroxide (KOH) is: *(1997)*
a. An amide
b. An amide and nitro compound
c. An ethyl isocyanide
d. An alkyl halide

33. When aniline reacts with oil of bitter almonds, (C_6H_5CHO) condensation takes place and benzal derivative is formed. This is known as *(1995)*

a. Schiff's base
b. Benedict's reagent
c. Millon's base
d. Schiff's reagent

34. The action of nitrous acid on an aliphatic primary amine gives: *(1994)*

a. Secondary amine
b. Nitro alkane
c. Alcohol
d. Alkyl nitrite

35. Which one of the following order is wrong, with respect to the property indicated? **[MR*]** *(1994)*

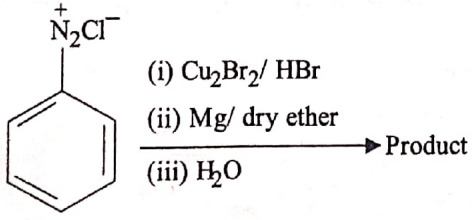
a. Benzoic acid > phenol > cyclohexanol (acid strength)
b. Aniline > cyclohexylamine > benzamide (basic strength)
c. Formic acid > acetic acid > propanoic acid (acid strength)
d. Fluoroacetic acid > chloroacetic acid > bromoacetic acid (acid strength).

36. For carbylamine reaction, we need hot alcoholic KOH and: **[MR*]** *(1992)*

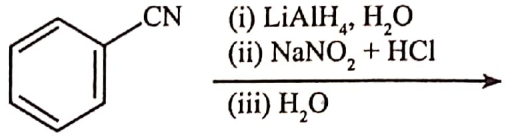
a. Any primary amine and chloroform
b. Chloroform and silver powder
c. A primary amine and an alkyl halide
d. A monoalkylamine and trichloromethane.

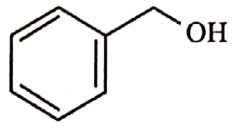
Diazonium Salt (Preparation, Physical & Chemical Properties)

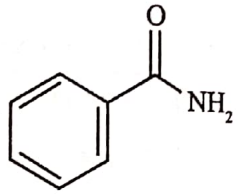
37. Identify the product in the following reaction: **[MR*]** *(2023)*

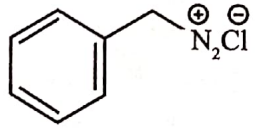


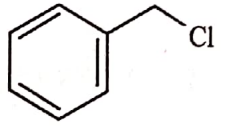
39. The product formed from the following reaction sequence is **[MR*]** *(2022)*



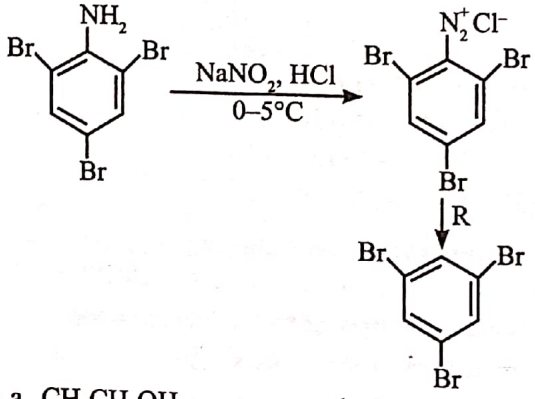
a. 

b. 

c. 

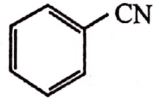
d. 

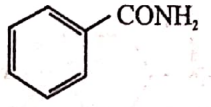
40. The reagent 'R' in the given sequence of chemical reaction is: *(2021)*

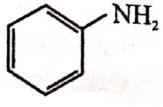


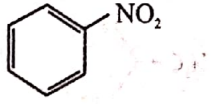
a. CH_3CH_2OH
b. HI
c. CuCN/KCN
d. H_2O

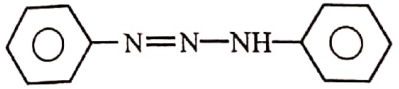
41. A given nitrogen-containing aromatic compound A reacts with Sn/HCl, followed by HNO_2 to give an unstable compound B. B, on treatment with phenol, forms a beautiful coloured compound C with the molecular formula $C_{12}H_{10}N_2O$. The structure of compound A is: *(2016 - II)*

a. 

b. 

c. 

d. 

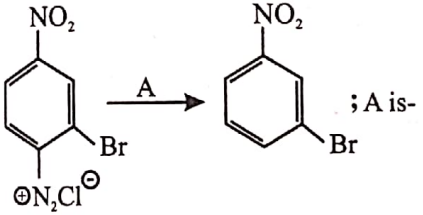
d. 

13. Which of the following will be most stable diazonium salt $RN_2^+X^-$? *(2014)*

a. $C_6H_5N_2^+X^-$ b. $CH_3CH_2N_2^+X^-$

c. $C_6H_5CH_2N_2^+H^-$ d. $CH_3N_2^+X^-$

14. In the reaction: *(2013)*

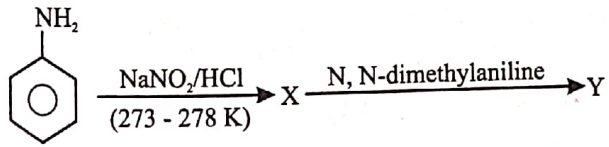


; A is-

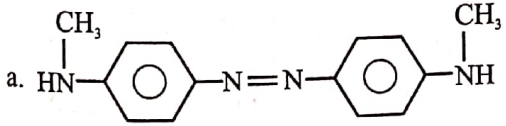
a. $HgSO_4/H_2SO_4$ b. Cu_2Cl_2

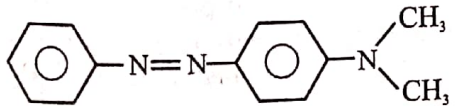
c. H_3PO_2 and H_2O d. H^+/H_2O

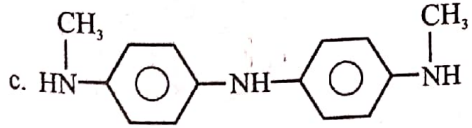
15. Aniline in a set of the following reactions yielded a coloured product Y

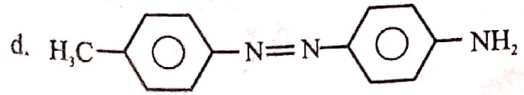


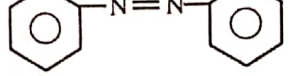
The structure of Y would be: **[MR*]** *(2010 Pre)*

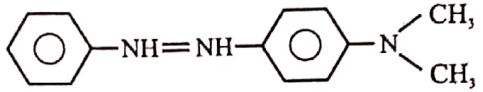
a. 

b. 

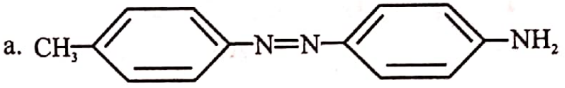
c. 

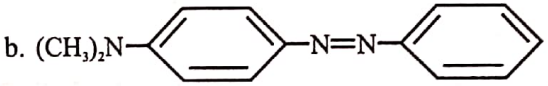
d. 

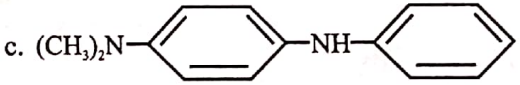
c. 

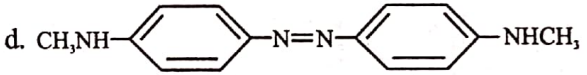
d. 

47. Aniline when diazotized in cold and then treated with dimethyl aniline gives a coloured product. Its structure would be :- *(2004)*

a. 

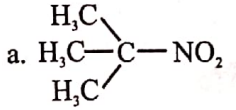
b. 

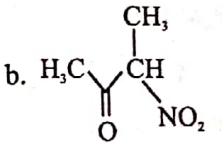
c. 

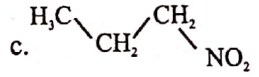
d. 

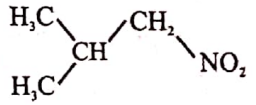
Nitrobenzene (Preparation and Properties)

48. Which one of the following nitro-compounds does not react with nitrous acid? *(2016 - II)*

a. 

b. 

c. 

d. 

49. The electrolytic reduction of nitrobenzene in strongly acidic medium produces *(2015)*

a. Azobenzene b. Aniline

c. p-aminophenol d. Azoxybenzene

@Kohinoorofficial1

Answer Key

1. (d)	**2.** (a)	**3.** (d)	**4.** (a)	**5.** (b)	**6.** (a)	**7.** (a)	**8.** (c)	**9.** (c)	**10.** (b)
11. (b)	**12.** (d)	**13.** (b)	**14.** (d)	**15.** (a)	**16.** (c)	**17.** (a)	**18.** (b)	**19.** (a)	**20.** (b)
21. (d)	**22.** (c)	**23.** (d)	**24.** (d)	**25.** (d)	**26.** (c)	**27.** (b)	**28.** (b)	**29.** (d)	**30.** (c)
31. (d)	**32.** (d)	**33.** (d)	**34.** (c)	**35.** (b)	**36.** (a)	**37.** (c)	**38.** (c)	**39.** (a)	**40.** (a)
41. (d)	**42.** (c)	**43.** (a)	**44.** (c)	**45.** (b)	**46.** (a)	**47.** (b)	**48.** (a)	**49.** (c)	**50.** (b)
51. (b)	**52.** (c)								

Explanations

1. (d) $CH_3CONH_2 \xrightarrow[(ii)\ H_3O^{\oplus}]{(i)\ LiAlH_4} CH_3CH_2NH_2$

$CH_3CONH_2 \xrightarrow{Br_2/KOH} CH_3NH_2$

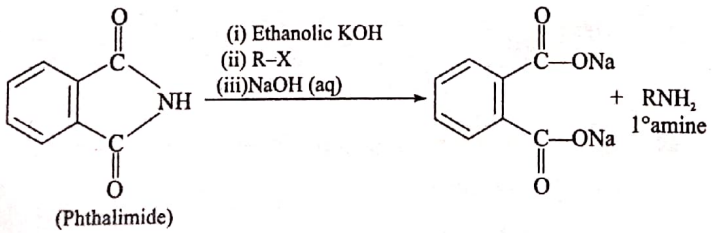
$CH_3CN \xrightarrow[(ii)\ H_3O^{\oplus}]{(i)\ LiAlH_4} CH_3CH_2NH_2$

$CH_3NC \xrightarrow[(ii)\ H_3O^{\oplus}]{(i)\ LiAlH_4} CH_3NHCH_3$

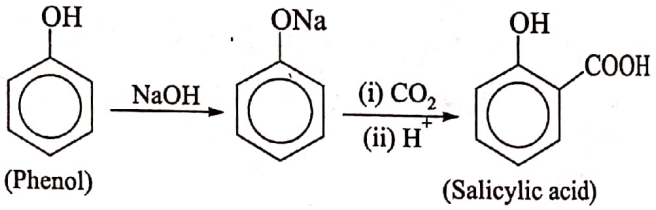
Methyl isocyanide gives a secondary amine, CH_3NHCH_3 upon reduction.

2. (a)

A. Gabriel synthesis



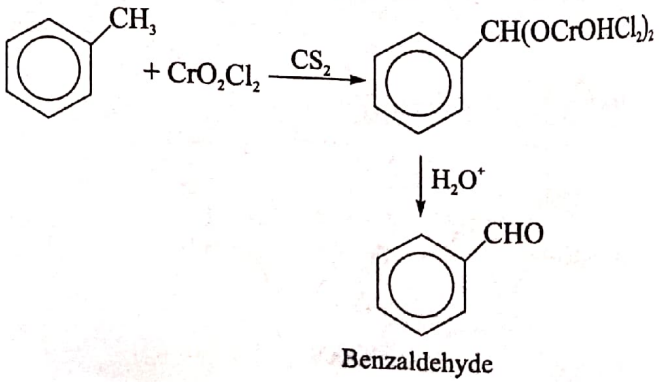
B. Kolbe synthesis



C. Williamson synthesis

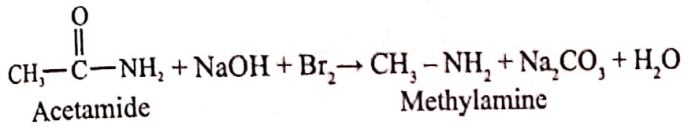
$$R{-}X + R'ONa \rightarrow \underset{\text{ether}}{R'OR} + NaX$$

D. Etard reaction

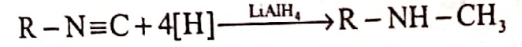


When potassium salt of phthalimide is treated with chlorobenzene, positive charge formation takes place on the benzene ring which is highly unstable. So, aryl halides are less reactive towards Gabriel phthalimide reaction.

5. **(b)** In Hoffman-Bromamide degradation, amides on reaction with NaOH & Br_2, yield methylamine. The corresponding 1° amine formed has 1C less than the parent chain. By product formed is Na_2CO_3.

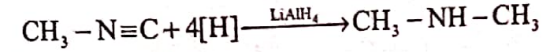


6. **(a)** Reduction of alkyl isocyanides in presence of $LiAlH_4$ yields secondary amines containing methyl, as one of the alkyl group.



2° amine

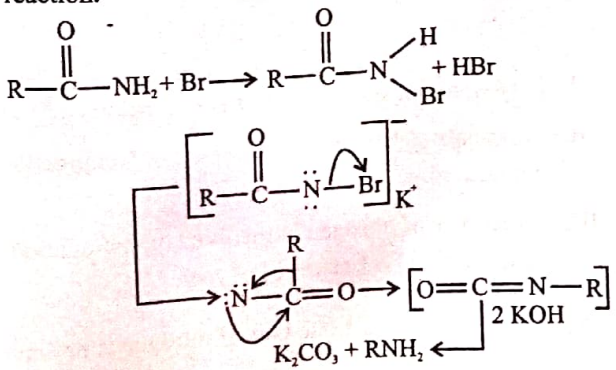
Eg.



Dimethyl amine

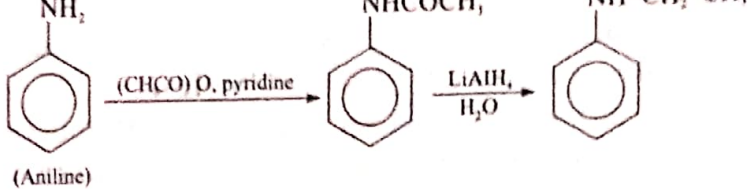
Whereas, alkyl cyanides give 1° amine on reduction.

7. **(a)** The reaction $RCONH_2 + Br_2 + KOH \rightarrow R\,NH_2$ is known as Hoffmann - bromamide reaction. The mechanism of the reaction.

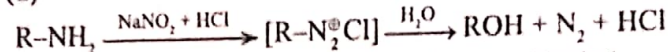


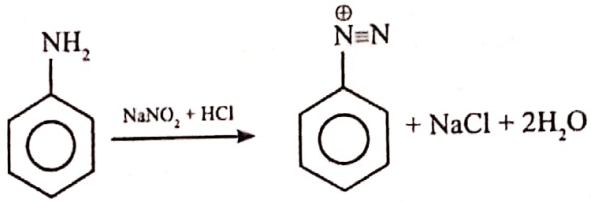
This reaction is used in the descent of series i.e. for preparing a lower homologous from a higher one.

8. **(c)** Amide can be converted into amine by Hoffmann - Bromamide reaction.



12. **(d)**

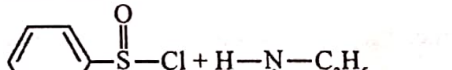


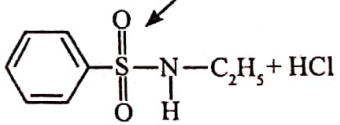


Aryl diazonium salt stable at low temperature (0–5°C)

Aniline aryl diazonium salt are resonance stabilised.

13. **(b)** Primary amines react with Hinsberg's reagent ($C_6H_5SO_2Cl$) to give a solid which dissolves in alkali.
Among the given options, C_2H_5–NH_2 being a primary amine reacts with Hinsberg's reagent to give a solid which dissolves in alkali.
Reaction:





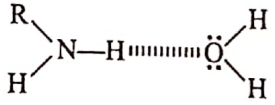
N-Ethylbenzenesulphonamide (soluble in alkali)

Hinsberg's reagent reacts with secondary amine ($C_2H_5NHCH_3$) to give N-Ethyl-N-Methyl benzene sulphonamide

14. **(d)** Aliphatic and aromatic primary amines when warmed with chloroform and alc. KOH form isocyanide or carbyl amine. This reaction is known as carbyl amine reaction. Aniline give carbyl amine test as it is primary aromatic amine.

undergo hydration through hydrogen bonding.

The protonated amines form H-bonds with H_2O molecules and release energy known as hydration energy and hence, get stabilized.

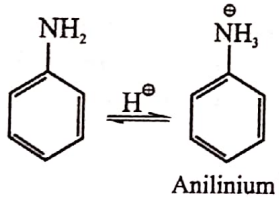


Greater is the number of hydrogen bond, higher will be the basicity. Number of hydrogen bond in primary amine is two, in secondary amine it is one and in case of tertiary amine, it is zero. So order of basicity: $1^\circ > 2^\circ > 3^\circ$

Inductive effect: –R group is electron releasing group, it will increase the basicity of amine by donation of electrons. As tertiary amine has more alkyl group so it is more basic. So, the order of basicity is $3^\circ > 2^\circ > 1^\circ$

The combined effect of the pushing effect of (+I effect, steric effect, solvation of amines) causes the basicity order to be: $2^\circ > 1^\circ > 3^\circ$

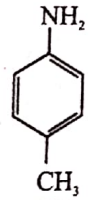
16. (c)



Anilinium ion

$-\overset{\oplus}{N}H_3$ is m-directing, hence besides para (51%) and ortho (2%), meta product (47%) is also formed in significant yield.

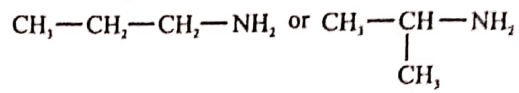
17. (a)



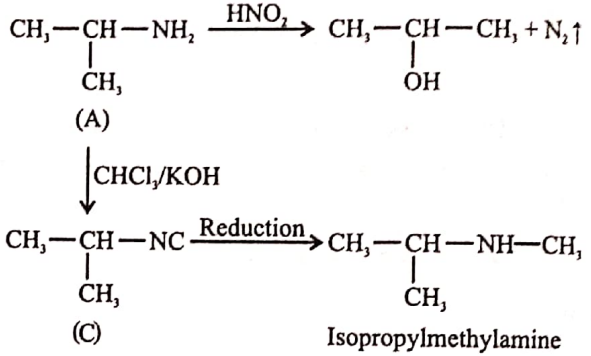
(III)

is more basic as compared to other two because CH_3 is a donating group which increases the basic strength of the group. The $-NO_2$ group is electron with drawing group, it will with-draw the electron density of amine toward's itself so, it will decrease the basicity of aniline.

20. (b) As A gives alcohol on treatment with nitrous acid thus it should be primary amine. C_3H_9N has two possible structure with $-NH_2$ group.

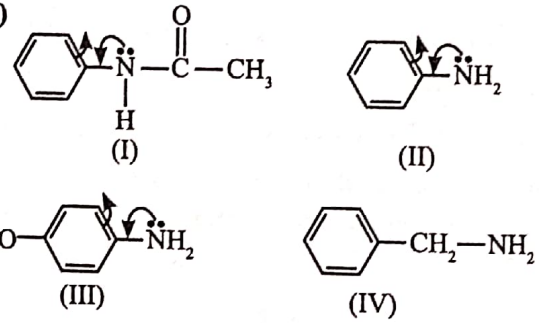


As it gives isopropylmethylamine thus it should be isopropyl amine not n-propyl amine.



(A) (C) Isopropylmethylamine

21. (d)

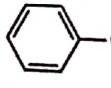


(I) (II) (III) (IV)

I. [Cross-conjugation] [— I effect of group $-\overset{\overset{O}{\|}}{C}-$] gp.

II. Lone-pair of Nitrogen is involved in Conjugation with benzene ring.

III. [Lone pair of nitrogen is involved in conjugation] with benzene ring [—I effect of oxygen.]

IV.  Lone pair of nitrogen is not involved in conjugation.

+ I effect of $-CH_2$ group.

$\therefore$ More electrons are present for donation and hence it is most basic among the given compounds.

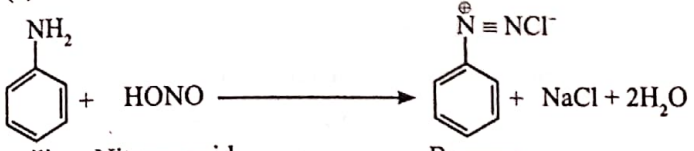
$R—NH_2$

Lone-pair of Nitrogen is involved in conjugation due to this it will decrease the basicity of $—NH_2$ group.

(c) $\underset{\text{Alkyl amine}}{R—NH_2} + \underset{\text{Nitrous acid}}{HONO} \xrightarrow{HONO\,(\text{nitrous acid})} [R—N_2^+Cl^-]$

$\xrightarrow{H_2O} \underset{\text{Alcohol}}{R—OH} + N_2 + HCl$

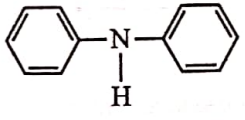
(d)



aniline Nitrous acid Benzene diazonium salt

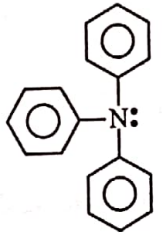
Aryl amines of reacting with nitrous acid forms diazonium salt and doesn't give phenols.

24. (d) Basicity $\propto \frac{+I, +R}{-I, -R}$



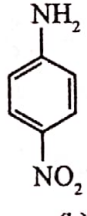
(a)

—R, —I effect of two phenyl rings decreases basicity



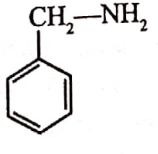
(b)

—R,— I effect of phenyl rings decrease basicity



(b)

—R, effect of phenyl ring and —I effect of $—NO_2$ group decreases basicity



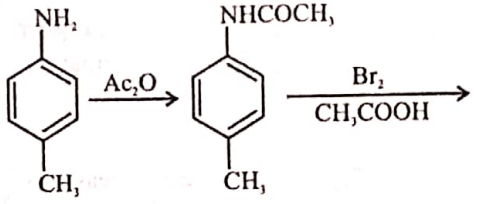
(d)

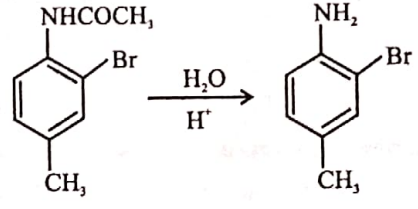
+I effect of $—CH_2$ group, increases the basicity

Reaction of aniline with ($NaNO_2$ + HCl) give diazonium salt, when it reacts with CuCN it gives Benzonitrile. Benzointrile on treatment with H_2/Ni (reducing agent) gives Benzyl amine.

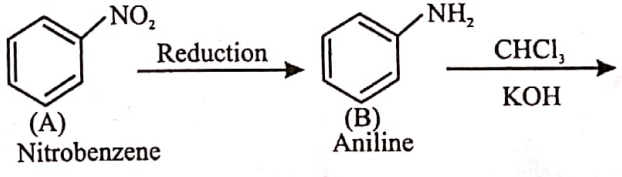
Further on addition of HONO, it gives Benzyl alcohol.

26. (c)

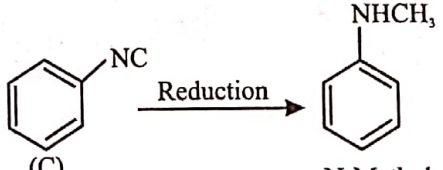




27. (b) 'C' must be an isocyanide and obtained from 1° amine by carbylamine reaction ($CHCl_3$ + KOH). Further 1° amine must be obtained by reduction of nitro hydrocarbon. So 'A' is nitrobenzene.

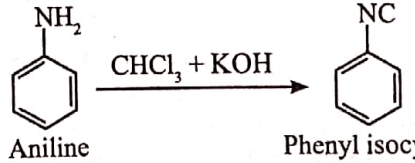


(A) Nitrobenzene (B) Aniline



(C) Phenyl isocyanide N-Methylaniline

28. (b)



Aniline Phenyl isocyanide

Carbyl amine reaction is used to prepare phenyl isocyanide.

(2, 4, 6-Tribromo Fluoro benzene)

(2, 4, 6-tribromo Benzene diazonium salt)

30. (c) $CH_3CH_2NH_2 + CHCl_3 + 3KOH \rightarrow$

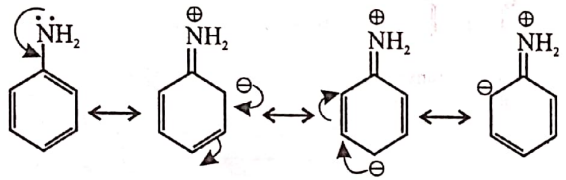
Ethyl amine Chloroform

$CH_3CH_2NC + 3\,KCl + 3\,H_2O$

Ethyl isocyanide

Isocyanide can be easily characterized by their offensive odour. The reaction is called carbylamine test.

31. (d)

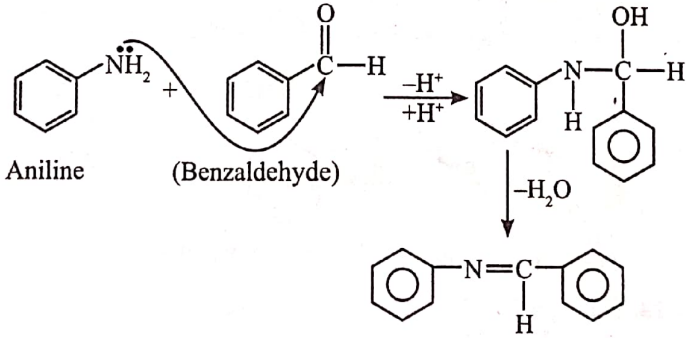


From resonating structure we can see electron density is more present on ortho and para position As, NO_2^+ electrophile can attack both *ortho* and *para* positions, therefore both a. and c. product will be obtained.

32. (d) $CH_3-C\equiv N \xrightarrow[H_2O]{\text{conc. HCl}} CH_3-CO-NH_2$

Acetonitrile Acetamide

33. (d)



Aniline (Benzaldehyde) (Benzylidene amine)

Schiff's base

34. (c) $R-NH_2 + HNO_2 \rightarrow ROH + N_2 + H_2O$

Primary amine Nitrous acid Alcohol

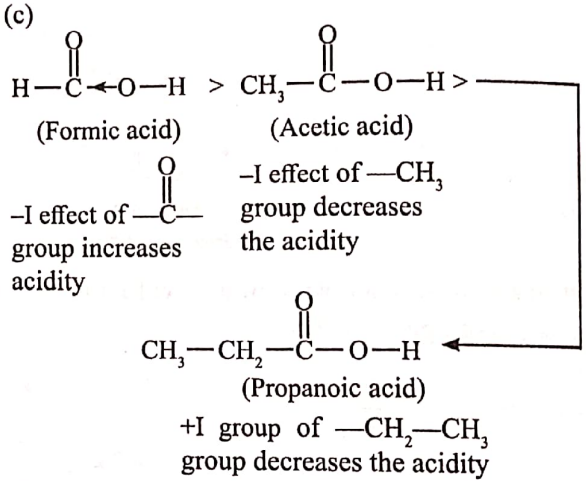
(Aniline)
– I, – R effect of phenyl ring decreases the basicity
(I)

(Cyclohexyl amine)
+ I effect of cyclo hexyl ring increases basicity
(II)

(Benzamide)
– I, – R effect of phenyl ring
– I effect of $-\overset{O}{\overset{\|}{C}}-$ group decreases the basicity
(III)

Basicity order: II > I > III

(c)



(Formic acid) (Acetic acid)

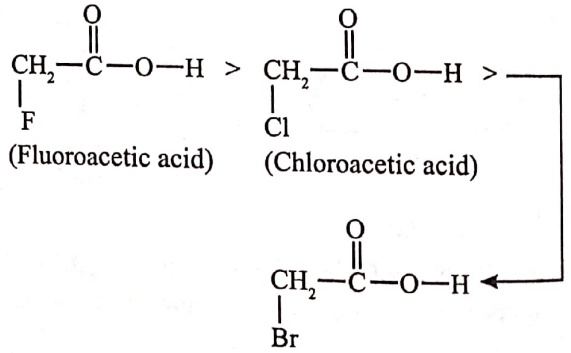
–I effect of $-\overset{O}{\overset{\|}{C}}-$ group increases acidity

–I effect of $-CH_3$ group decreases the acidity

(Propanoic acid)

+I group of $-CH_2-CH_3$ group decreases the acidity

(d)



(Fluoroacetic acid) (Chloroacetic acid)

(Bromoacetic acid)

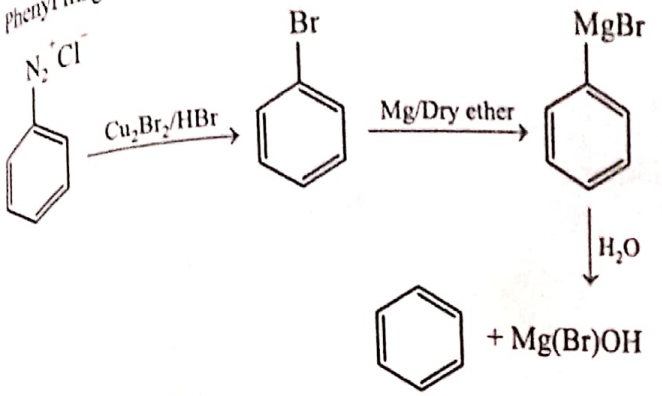
electron with drawing nature of fluorine is more than chlorine and bromine. So, fluoroacetic acid is more acidic among the give compounds.

36. (a) In carbylamines reaction, primary amines on heating with chloroform in presence of alcoholic KOH form isocyanides (or carbylamines). It is used to distinguish 1^0 amines from 2^0 and 3^0 amines.

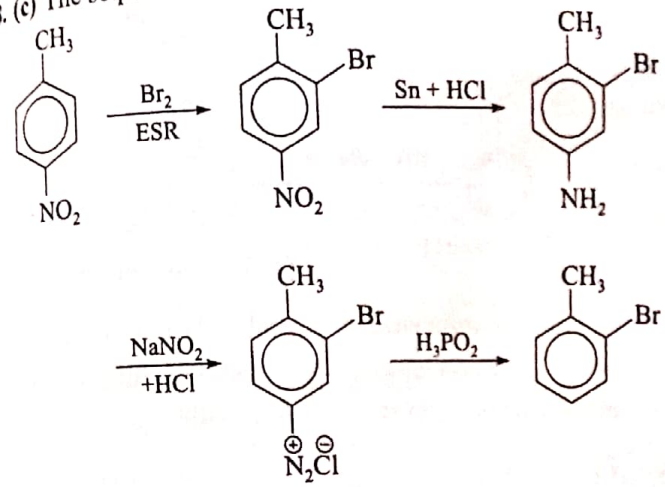
$R-NH_2 + CHCl_3 + 3KOH \xrightarrow{\text{(alc.)}} RNC + 3KCl + 3H_2O$

(Amine) (Isocyanide)

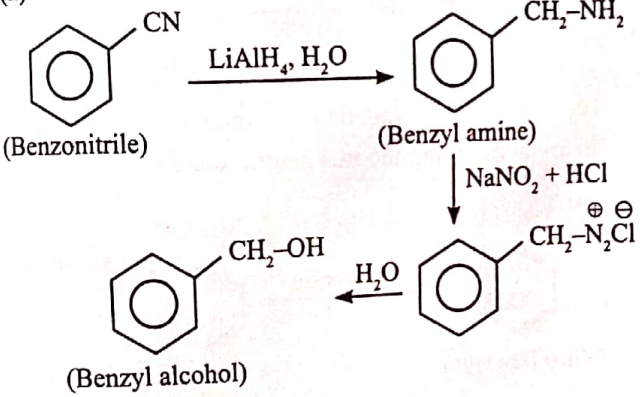
37. (c) Bromobenzene is formed in first step (Sandmeyer reaction), which further gives phenyl magnesium bromide. Phenyl magnesium bromide further gives benzene with water.



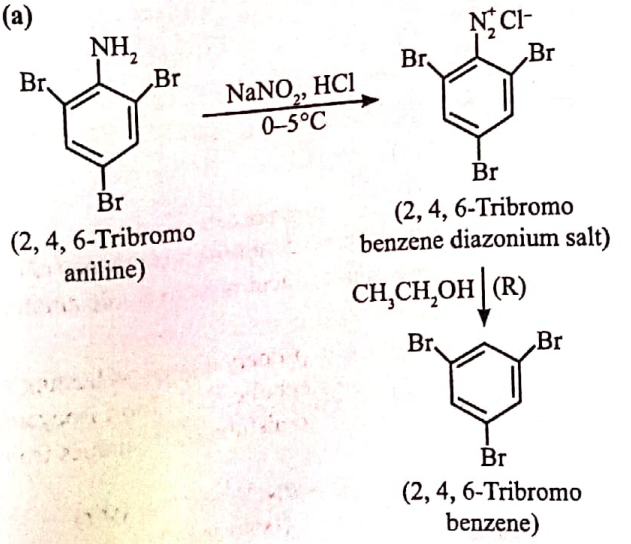
38. (c) The sequence of reaction can be represented as:



39. (a)



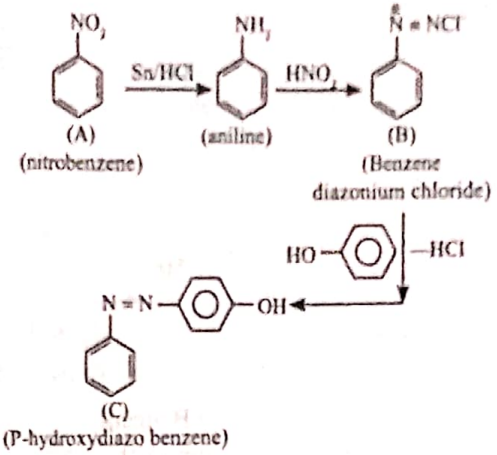
40. (a)



Hence, reagent R is CH_3CH_2OH.

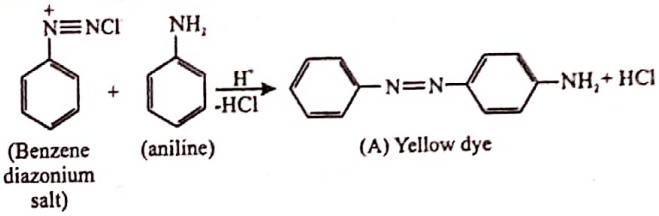
Certain mild reducing agents like ethanol reduce diazonium salts to arenes.

41. (d) A is nitro containing aromatic compound.

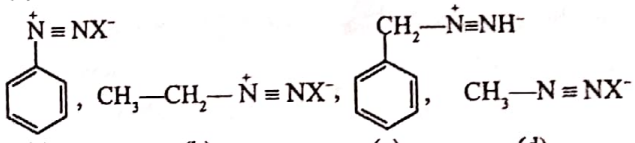


Sn/HCl is ruducing agent it will reduce nitrobenzene to aniline after reacting with HNO_2 ($NaNO_2$ + HCl) it will give Benzene diazonium chloride which is a method of preparation of diazonium salt. After this, when phenol reacts with Benzene diazonium salt, orange dye (p-hydroxy diazo Benzene) is formed by the removal of HCl.

42. (c)

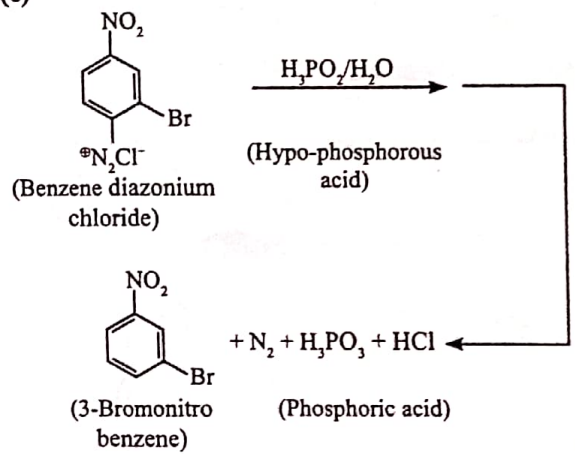


43. (a)



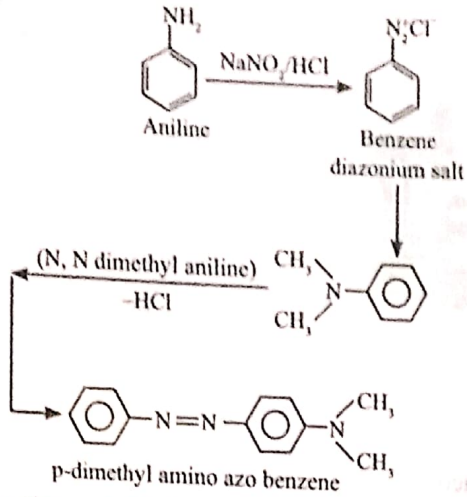
Diazonium salt is stabilised by resonance in Structure (a). So, (a) will be most stable diazonium salt.

44. (c)



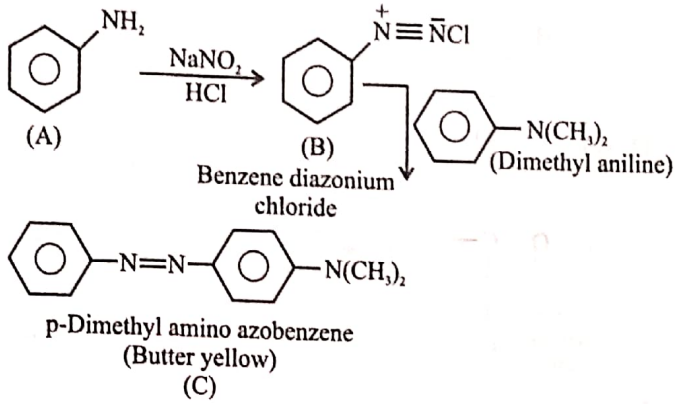
Hypophosphorous acid (H_3PO_2) is a mild reducing agent. Therefore, it reduces diazonium salts to arenes and themselves get oxidized to phosphoric acid.

45. (b)

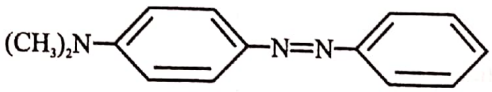


Reaction of [$NaNO_2$ + HCl] will give HONO. When HNO_2 (nitrous acid) is reacted with aniline it will give Benzenediazonium salt, when it reacts with N, N-dimethylaniline, it gives p-dimethyl amino azo benzene by removal the of HCl.

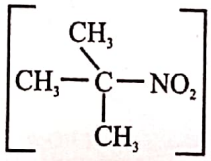
46. (a)



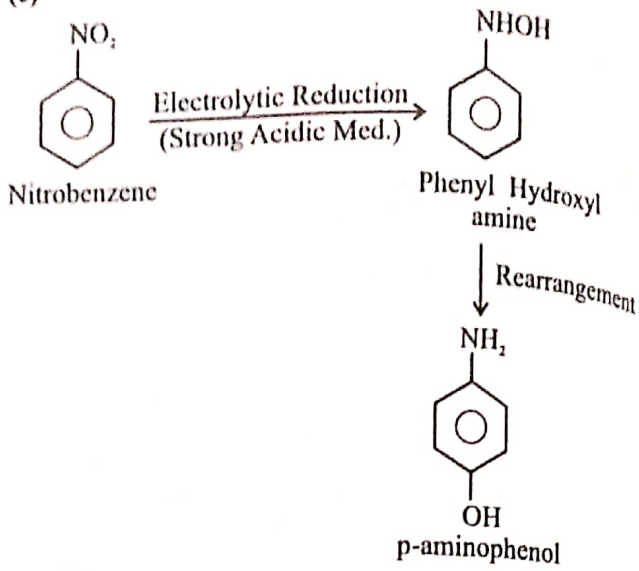
47. (b) The structure of the product formed would be:



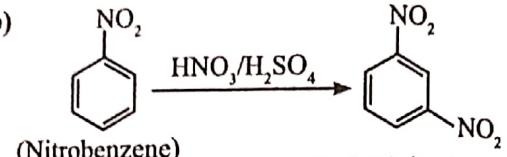
48. (a) 3° - NO_2 compounds do not react with HNO_2 (nitrous acid) because of absence of α-H.



49. (c)

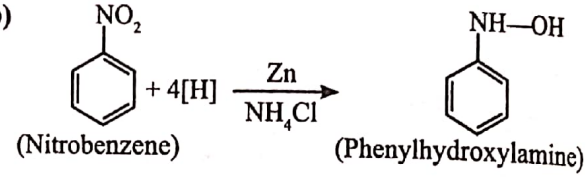


50. (b)



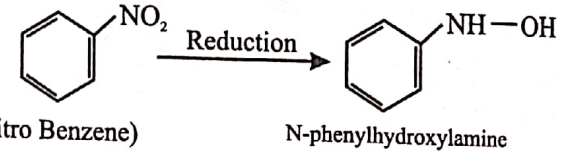
Nitration of nitrobenzene will take place in the presence of HNO_3/H_2SO_4. As Nitro group is meta-directing, so incoming group will attach on attach meta position.

51. (b)



The reagent, Zn/NH_4Cl reduce nitrobenzene to Phenylhydroxylamine in a neutral medium.

52. (c)



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TgId - @kohinoorofficial1

CHAPTER 11

Biomolecules

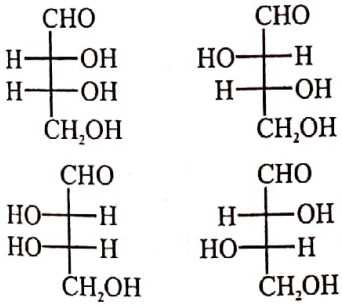
Carbohydrates

1. Sucrose on hydrolysis gives: [MR*] *(2020)*
   a. α-D-Glucose + β-D-Glucose
   b. α-D-Glucose + β-D-Fructose
   c. α-D-Fructose + β-D-Fructose
   d. β-D-Glucose + α-D-Fructose

2. Which of the following statement is not true about glucose? *(2020-Covid)*
   a. It contains five hydroxyl groups
   b. It is a reducing sugar
   c. It is an aldopentose
   d. It is an aldohexose

3. The difference between amylose and amylopectin is *(2018)*
   a. Amylopectin have 1 → 4 α-linkage and 1 → 6 α-linkage
   b. Amylose have 1 → 4 α-linkage and 1 → 6 β-linkage
   c. Amylose is made up of glucose and galactose
   d. Amylopectin have 1 → 4 α-linkage and 1 → 6 β-linkage

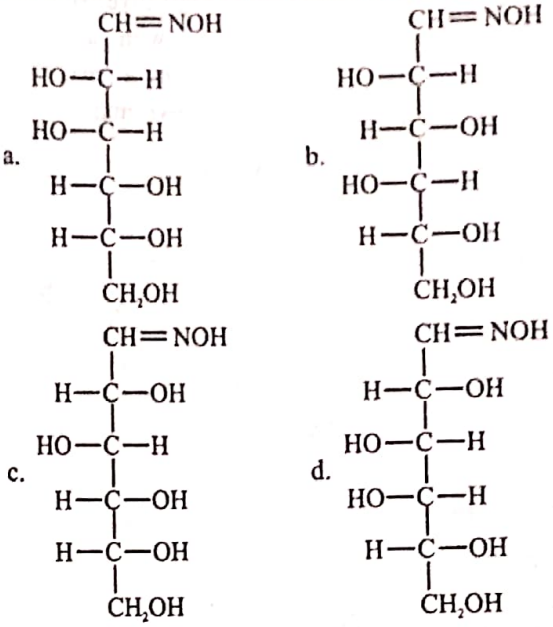
4. The correct corresponding order of names of four aldoses with configuration given below: [MR*] *(2016 - II)*



   a. L-erythrose, L-threose, L-erythrose, D-threose
   b. D-threose, D-erythrose, L-threose, L-erythrose
   c. L-erythrose, L-threose, D-erythrose, D-threose
   d. D-erythrose, D-threose, L-erythrose, L-threose

5. Which one given below is a non-reducing sugar? [MR*] *(2016 - I)*
   a. Sucrose
   b. Maltose
   c. Lactose
   d. Glucose

6. D(+) glucose reacts with hydroxyl amine and yields an oxime. The structure of the oxime would be: *(2014)*



   a.
   b.
   c.
   d.

7. Which one of the following sets of mono-saccharides forms sucrose? *(2012 Pre)*
   a. α-D-Glucopyranose and β-D-fructopyranose
   b. α-D-Galactopyranose and α-D-Glucopyranose
   c. α-D-Glucopyranose and β-D-fructofuranose
   d. α-D-Glucopyranose and α-D-fructofuranose

8. Which one of the following statements is not true regarding (+) lactose? [MR*] *(2011 Pre)*
   a. On hydrolysis (+) lactose gives equal amount of D (+) glucose and D (+) galactose
   b. (+) lactose is a β-glucoside formed by the union of a molecule of D (+) glucose and a molecule of D (+) galactose
   c. (+) lactose is a reducing sugar and does not exhibit mutarotation
   d. (+) lactose, $C_{12}H_{22}O_{11}$ contains 8-OH groups

9. Fructose reduces Tollen's reagent due to: *(2010 Mains)*
   a. Asymmetric carbons
   b. Primary alcoholic group
   c. Secondary alcoholic group
   d. Enolisation of fructose followed by conversion to aldehyde by base

10. Which one of the following does *not* exhibit the phenomenon of mutarotation? *(2010 Pre)*
a. (–) Fructose
b. (+) Sucrose
c. (+) Lactose
d. (+) Maltose

11. Number of chiral carbons in β–D–(+)– glucose is: *(2004)*
a. Six
b. Three
c. Four
d. Five

12. Glycolysis is: *(2003)*
a. Oxidation of glucose to glutamate
b. Conversion of pyruvate of citrate
c. Oxidation of glucose to pyruvate
d. Conversion of glucose to haem

13. Which is correct statement? *(2001)*
a. Starch is polymer of α-glucose
b. Amylose is a component of cellulose
c. Protiens are composed of only one type of amino acid
d. In cyclic structure of fructose, there are four carbons and one oxygen atom

14. Which of following give positive Fehling solution test? [MR*] *(2001)*
a. Sucrose
b. Glucose
c. Fats
d. Protein

15. α-D-glucose and β-D-glucose are: [MR*] *(2000)*
a. Epimers
b. Anomer
c. Enantiomers
d. Diastereomers

16. Which of the following is the sweetest sugar? *(1999)*
a. Sucrose
b. Glucose
c. Fructose
d. Maltose

17. Glucose molecule reacts with 'X' number of molecules of phenylhydrazine to yield osazone. The value of 'X' is: [MR*] *(1998)*
a. Four
b. One
c. Two
d. Three

18. The oxidation of glucose is one of the most important reactions in a living cell. What is the number of ATP molecules generated in cells from one molecule of glucose? *(1995)*
a. 28
b. 38
c. 12
d. 18

19. The α-D-glucose and β-D-glucose differ from each other due to difference in carbon atom with respect to its: *(1995)*
a. Number of OH groups
b. Size of hemiacetal ring
c. Conformation
d. Configuration

20. On hydrolysis of starch, we finally get: *(1991)*
a. Glucose
b. Fructose
c. Both (a) and (b)
d. Sucrose

Proteins

21. The **incorrect** statement about denaturation of proteins is : [MR*] *(2022 Re)*
a. Uncoiling of the helical structure takes place.
b. It results due to change of temperature and/ or pH
c. It results in loss of biological activity of proteins.
d. A protein is formed from amino acids linked by peptide bonds.

22. Which of the following is a basic amino acid? [MR*] *(2020)*
a. Alanine
b. Tyrosine
c. Lysine
d. Serine

23. The non-essential amino acid among the following is: [MR*] *(2019)*
a. Valine
b. Leucine
c. Alanine
d. Lysine

24. Which of the following compounds can form a zwitter ion? *(2018)*
a. Aniline
b. Acetanilide
c. Glycine
d. Benzoic acid

25. In a protein molecule, various amino acids are linked together by: *(2016 - I)*
a. Dative bond
b. α-glycosidic bond
c. β-glycosidic bond
d. Peptide bond

26. Which of the statements about "Denaturation" given below are correct?
Statements: *(2011 Mains)*
(A) Denaturation of proteins causes loss of secondary and tertiary structures of the protein
(B) Denaturation leads to the conversion of double strand of DNA into single strand
(C) Denaturation affects primary structure which gets distorted
a. (A) and (B)
b. (A), (B) and (C)
c. (B) and (C)
d. (A) and (C)

27. Which functional group participates in disulphide bond formation in proteins? *(2005)*
a. Thiolactone
b. Thiol
c. Thioether
d. Thioester

28. The correct statement in respect of protein haemoglobin is that it: *(2004)*
a. Maintains blood sugar level
b. Acts as an oxygen carrier in the blood
c. Forms antibodies and offers resistance to diseases
d. Functions as a catalyst for biological reactions

30. The helical structure of protein is stabilized by: [MR*] *(2004)*

a. Hydrogen bonds
b. Ether bonds
c. Peptide bonds
d. Dipeptide bonds

31. Which is not true statement? *(2002)*

a. α-carbon of α-amino acid is asymmetric
b. All proteins are found in L-form
c. Human body can synthesise all proteins they need
d. At pH = 7 both amino and carboxylic groups exist in ionised form

32. (peptide bond)

Which statement is incorrect about peptide bond? *(2001)*

a. C–N bond length in proteins is longer than usual bond length of C–N bond
b. Spectroscopic analysis show planar structure of group
c. C–N bond length in protiens is smaller than usual bond length of C–N bond
d. None of above

33. Haemoglobin is: *(1997)*

a. A vitamin
b. A carbohydrate
c. An enzyme
d. A globular protein

34. The secondary structure of a protein refers to: *(1995)*

a. Regular folding patterns of continuous portions of the polypeptide chain
b. Three-dimensional structure, specially the bond between amino acid residues that are distant from each other in the polypeptide chain
c. Mainly denatured proteins and structures of prosthetic groups
d. Linear sequence of amino acid residues in the polypeptide chain.

37. The RBC deficiency is deficiency disease of: [MR*] *(2021)*

a. Vitamin B_6
b. Vitamin B_1
c. Vitamin B_2
d. Vitamin B_{12}

38. Deficiency of which vitamin causes osteomalacia? *(2020-Covid)*

a. Vitamin D
b. Vitamin K
c. Vitamin E
d. Vitamin A

39. Deficiency of vitamin B_1 causes the disease: *(2012 Pre)*

a. Sterility
b. Convulsions
c. Beri-Beri
d. Cheilosis

40. Which of the following is not a fat soluble vitamin? [MR*] *(2011 Mains)*

a. Vitamin E
b. Vitamin A
c. Vitamin B complex
d. Vitamin D

41. Which of the following is water-soluble? *(2007)*

a. Vitamin E
b. Vitamin K
c. Vitamin A
d. Vitamin B

42. The human body does not produce: *(2006)*

a. DNA
b. Vitamins
c. Hormones
d. Enzymes

43. The enzyme which hydrolysis triglycerides to fatty acids and glycerol is called: *(2004)*

a. Lipase
b. Zymase
c. Pepsin
d. Maltase

44. Vitamin B_{12} contains: [MR*] *(2003)*

a. Fe(II)
b. Co(III)
c. Zn(II)
d. Ca(II)

45. Which of the following is correct? *(2001)*

a. Cyclo-heptane is an aromatic compound
b. Diastase is an enzyme
c. Acetophenone is an ether
d. All the above

46. The function of enzymes in the living system is to: *(1997)*

a. Catalyse biochemical reactions
b. Provide energy
c. Transport oxygen
d. Provide immunity

c. Both (a) and (b)

d. None of these

Nucleic Acids

50. Given below are two statements: **[MR*]** *(2023)*

Statement I: A unit formed by the attachment of a base to 1' position of sugar is known as nucleoside

Statement II: When nucleoside is linked to phosphorous acid at 5'-position of sugar moiety, we get nucleotide.

In the light of the above statements, choose the correct answer from the options given below:

a. Statement I is false but Statement II is true.

b. Both Statement I and Statement II are true.

c. Both Statement I and Statement II are false.

d. Statement I is true but Statement II is false.

51. The central dogma of molecular genetics states that the genetic information flows from: *(2016 - II)*

a. Amino acids → Proteins → DNA

b. DNA → Carbohydrates → Proteins

c. DNA → RNA → Proteins

d. DNA → RNA → Carbohydrates

52. The correct statement regarding RNA and DNA, respectively is: **[MR*]** *(2016 - I)*

a. The sugar component in RNA is 2′-deoxyribose and the sugar component in DNA is arabinose

b. The sugar component in RNA is arabinose and the sugar component in DNA is 2′-deoxyribose

c. The sugar component in RNA is ribose and the sugar component in DNA is 2′-deoxyribose

d. The sugar component in RNA is arabinose and the sugar component in DNA is ribose

53. The segment of DNA which acts as the instrumental manual for the synthesis of the protein is: *(2009)*

a. Ribose

b. Gene

c. Nucleoside

d. Nucleotide

57. A sequence of how many [illegible] in messenger RNA makes a codon for an amino acid? *(2004)*

a. Four

b. One

c. Two

d. Three

58. Phospholipids are esters of glycerol with: *(2001)*

a. Three carboxylic acid residues

b. Two carboxylic acid residues and one phosphate group

c. One carboxylic acid residue and two phosphate groups

d. Three phosphate groups

59. Chargaff's rule states that in an organism: **[OS]** *(2003)*

a. Amount of adenine (A) is equal to that of thymine (T) and the amount of guanine (G) is equal to thatof cytosine (C)

b. Amount of adenine (A) is equal to that of guanines (G) and the amount of thymine (T) is equal to that of cytosine (C)

c. Amount of adenine (A) is equal to that of cytosine (C) and the amount of thymine (T) is equal to that of guanine (G)

d. Amounts of all bases are equal

60. Which of the following is correct about H-bonding in nucleotide? *(2001)*

a. A–T, G–C

b. A–G, T–C

c. G–T, A–C

d. A–A, T–T

61. The number of molecules of ATP produced in the lipid metabolism of a molecule of palmitic acid is: *(1998)*

a. 130

b. 36

c. 56

d. 86

62. In DNA, the complementary bases are: *(1998)*

a. Adenine and thymine, guanine and cytosine

b. Uracil and adenine, cytosine and guanine

c. Adenine and guanine, thymine and cytosine

d. Adenine and thymine, guanine and uracil

63. The couplings between base units of DNA is through: *(1992)*

a. Hydrogen bonding

b. Electrostatic bonding

c. Covalent bonding

d. Van der Waals forces

Hormones

64. Which of the following hormones is produced under the conditions of stress which stimulate glycogenolysis in the liver of human beings? *(2014)*

a. Thyroxin b. Insulin
c. Adrenaline d. Estradiol

65. Which of the following hormones contains iodine? [MR*] *(2009)*

a. Testosterone b. Adrenaline
c. Thyroxine d. Insulin

66. Which of the following is an amine hormone? *(2008)*

a. Insulin b. Progesterone
c. Thyroxine d. Oxypurin

67. Which one of the following is a peptide hormone? *(2006)*

a. Adrenaline b. Glucagon
c. Testosterone d. Thyroxine

68. The hormone that helps in the conversion of glucose to glycogen is: *(2004)*

a. Bile acids b. Adrenaline
c. Insulin d. Cortisole

69. Which one is responsible for production of energy in bioreaction? *(2000)*

a. Thyroxine b. Adrenaline
c. Oestrogen d. Progesterone

Answer Key

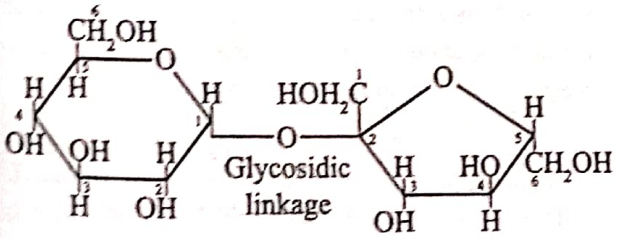
1. (b)	2. (c)	3. (a)	4. (d)	5. (a)	6. (c)	7. (c)	8. (c)	9. (d)	10. (b)
11. (c)	12. (c)	13. (a)	14. (b)	15. (b)	16. (c)	17. (d)	18. (b)	19. (d)	20. (a)
21. (d)	22. (c)	23. (c)	24. (c)	25. (d)	26. (a)	27. (b)	28. (b)	29. (b)	30. (a)
31. (b)	32. (a)	33. (d)	34. (a)	35. (d)	36. (d)	37. (d)	38. (a)	39. (c)	40. (c)
41. (d)	42. (b)	43. (a)	44. (b)	45. (b)	46. (a)	47. (b)	48. (c)	49. (b)	50. (d)
51. (c)	52. (c)	53. (b)	54. (b)	55. (c)	56. (c)	57. (d)	58. (b)	59. (a)	60. (a)
61. (a)	62. (a)	63. (a)	64. (c)	65. (c)	66. (c)	67. (b)	68. (c)	69. (a)	

Explanations

1. **(b)** Sucrose is composed of one mole of α-D-glucose and β-D-fructose, connected by glycosidic linkage at 1 and 2 carbon atoms of glucose and fructose respectively.

When sucrose is hydrolysed by HCl in alcoholic medium, mixture of α-D-glucose and β-D-fructose is obtained.

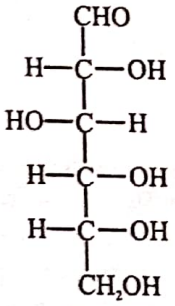
$$\text{Sucrose} \xrightarrow{\text{Hydrolysis}} \alpha\text{-D-Glucose} + \beta\text{-D-Fructose}$$



α-D-Glucose β-D-Fructose

2. **(c)**

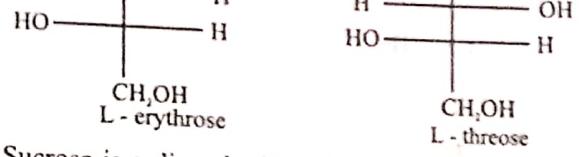
- Glucose (also known as dextrose) is a carbohydrate compound consisting of six carbon atoms and an aldehyde group and known as aldohexose.
- There are 5 –OH groups are present.
- It is a reducing sugar as it contains –CHO group.



Glucose

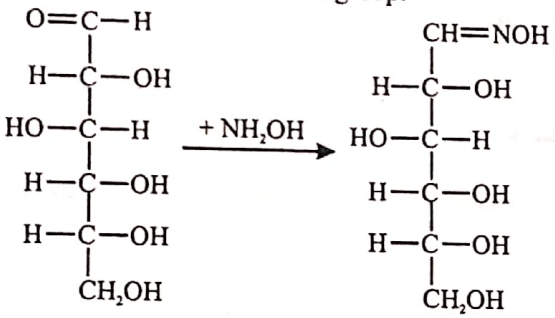
3. **(a)** Amylose and Amylopectin are polymers of α- D-glucose, so, β-link is not possible.

Amylose is a long unbranched chain having 200 – 1000 α – D – (+) – glucose units that are held together by C1 – C4 glycosidic linkage. Amylopectin is a branched chain polymer of α-D-glucose units having C1 – C4 glycosidic linkage while branching takes place at C1 – C6 glycosidic linkage. So, option (a) should be the correct.



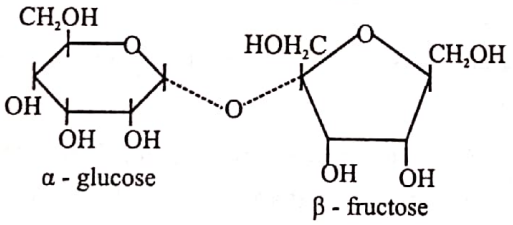
5. (a) Sucrose is a disaccharide which on hydrolysis gives an equimolar mixture of D-(+)-glucose and D-(–) fructose. These two units are joined together by a glycosidic linkage between C1 of α-D-glucose and C2 of β-D-fructose. As reducing groups of glucose and fructose will take part in glycosidic bond formation, sucrose is known as a non-reducing sugar.

6. (c) When D(+) glucose reacts with hydroxylamine, the formation of an oxime takes place. In this reaction, –CHO group reacts with hydroxylamine to form CH=NOH group which is known as an oxime group.

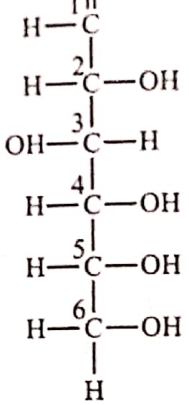


D (+) glucose Glucoxime

7. (c) Sucrose is a non – reducing dissacharide with fructose & glucose as monomers. Sucrose on hydrolysis yield an equimolar mixture of D-(+)-glucose and D-(–) fructose. These two monosaccharide units are bonded together by having glycosidic linkage between C1 of α-D-glucose and C2 of β-D-fructose.



8. (c) Lactose is composed of β-D-galactose and β-D-glucose having linkage between C1 of galactose and C4 of glucose. At C1 of glucose, free –CHO group is present due to which it is a reducing sugar and hence exhibits mutarotation.



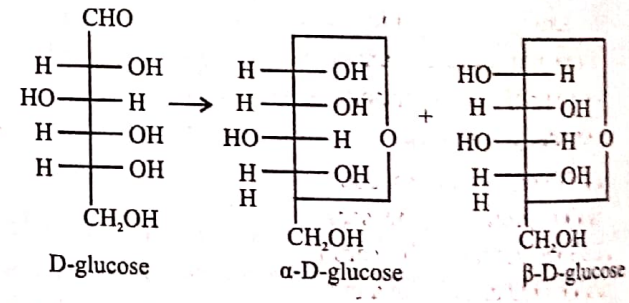
The carbon atom 2,3,4 & 5 each have four different groups attached to them. So, there are 4-chiral carbon atoms.

12. (c) Glycolysis is the first stage in the oxidation of glucose. It is an anaerobic process & involves the degradation of glucose into two molecules of pyruvate with the generation of two molecules of ATP.

13. (a) Starch is also known as amylum which occurs in all green plants. A molecule of starch $(C_6H_{10}O_5)_n$ is built of a large no. of α-glucose rings joined through oxygen atoms. It is a polymer of α-glucose and consists of amylose and amylopectin.

14. (b) Glucose reduces fehling test solution because glucose has free –CHO group which is readily oxidised.

15. (b) Glucose forms a stable hemiacetal between the -CHO group and the -OH group on the 5th carbon. In this process, the 1st 'C' atom becomes asymmetric giving two isomers which differ in the configuration of the asymmetric carbon. These two isomers are called as anomers.



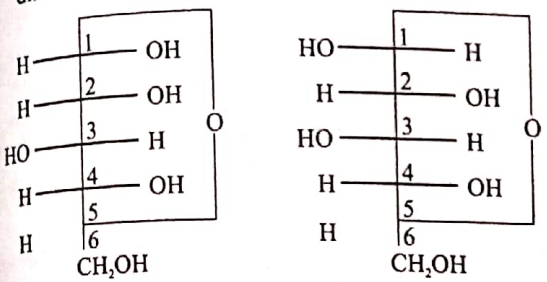
D-glucose α-D-glucose β-D-glucose

16. (c) Fructose is known as the sweetest naturally occurring sugar which is estimated to be twice as sweet as sucrose.

molecules of glucose is required to form osazone.

18. (b) $C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2 + 6H_2O + 38$ ATP

19. (d) α-D-glucose and β-D-glucose differ from each other due to difference in configuration at C1 atom.



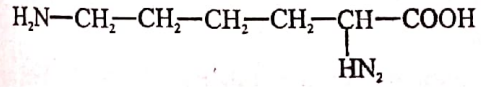
α – D – glucose β – D – glucose

20. (a) Glucose is produced commercially by the hydrolysis of starch by boiling it with dil. H_2SO_4 at 393 K under pressure of 2-3 bar.

$$\underset{\text{Starch}}{(C_6H_{10}O_5)_n} + nH_2O \xrightarrow[393,\ 2\text{-}3\text{bar}]{H^+} \underset{\text{Glucose}}{nC_6H_{12}O_6}$$

21. (d) Protein formation is not related to the denaturation of proteins.

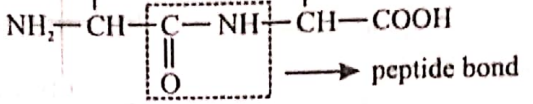
22. (c) Lysine is known as a basic amino acid because at neutral pH, it contains basic side chain. It has an isoelectric pH of 7. It is an essential amino acid. It contains a net positive charge at physiological pH values.



Lysine

23. (c) Amino acids which can be synthesised in our body are called non-essential amino acids. These are not taken up as food supplements. Among the given options, alanine is a non-essential amino acid.

24. (c) Glycine contains both acidic (carboxyl group) and basic (amino group) in the same molecule. In the presence of an aqueous solution, the carboxyl group can lose a proton while amino acid can accept a proton which results in the formation of dipolar ion known as zwitter ion. This ion is neutral but contains both negative and positive charges.



26. (a) Denaturation means distortion in protein structure of enzyme thus inhibiting enzymatic activity. Denaturation of protiens at high temperature causes the loss of secondary & tertiary structure of proteins.

Also in case of DNA, it leads to distortion from double stranded to single - stranded structure.

27. (b) Thiol group (R-SH) is present for linking disulphide bonds of two sulphur containing amino acids methionine & cystenine.

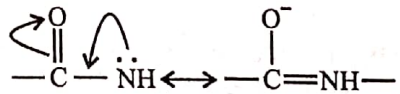
28. (b) Haemoglobin acts as an oxygen carrier in the blood. In this protein, 4 Fe^{2+} ions of each haemoglobin can bind with 4 molecules of O_2 & form oxyhaemoglobin.

29. (b) A peptide bond is formed by joining the carboxyl group of one amino acid to the amino group of another. The structure given in option (b) represents the peptide chain.

30. (a) Due to the formation of H-bond between amide group of the same peptide chain, i.e., NH group in one unit is linked to carbonyl oxygen of the third unit by H-bonding. This hydrogen bonding is responsible for holding helix in a position.

31. (b) Proteins exist in both D and L-form except glycine. Most naturally occurring amino acids have L-configuration.

32. (a) Peptides bonds is formed by the reaction of one –COOH group of one amino acid with the -NH_2 group of another amino acid and is represented as:



Due to some double bond character, the C - N bond length is smaller in proteins.

33. (d) Haemoglobin is a globular protein of four subunits, each subunit having a heme moiety and a polypeptide chain (Two a and two b chains).

34. (a) The secondary structure of a protein refers to regular folding patterns of continuous portions of the polypeptide chain. This structure refers to the shape in which a long polypeptide chain can exist. This structure exists in two different types of structures-α-helix and β-pleated.

35. (d) Cheilosis that is fissuring at corners of mouth and lips takes place due to deficiency of vitamin B_2 (Riboflavin).

36. (d) Except option 4, rest are correct statements. As enzymes are also known as biocatalyst and are specific in nature. Like chemical catalysts, enzymes reduce the activation energy of bio process. Enzymes have high molecular mass made up of protein chains. Proteins are defined as the combination of amino acids that are joined together by peptide bonds.

37. (d) Deficiency of vitamin B_6 causes convulsions.

Deficiency of vitamin B_1 causes disease beri beri (loss of appetite, retarded growth).

Deficiency of vitamin B_2 causes disease cheilosis, digestive disorders and burning sensations of the skin.

Deficiency of vitamin B_{12} causes Pernicious anaemia (RBC deficient in haemoglobin).

In this deficiency, body does not contain enough healthy red blood cells. Symptoms include fatigue and pallor. Jaundice can also be the presenting symptom due to increased hemolysis which is caused due to impaired red blood cell formation.

38. (a) Osteomalacia is a vitamin-D deficiency disease, in which bone density decrease and bones get softer. This disease results in abnormal osteoid mineralization due to which breaking of bone takes place at a faster rate that it takes time to re-form. Its most common symptoms are pain in the bones, bones, bone fractures, and weakness of muscles.

39. (c) Vitamin B_1 deficiency causes Beri – Beri. Symptoms of beri-beri include difficulty in walking, loss of sensation in hands and feets, pain, mental confusion, paralysis of the lower legs etc.

40. (c) Vitamin B complex (B_3) is water soluble. This vitamin cannot be stored in the body and hence, must be consumed each day. As it is dissolve in water, it gets easily absorbed into the tissue of the body.

41. (d) Vitamin B is water soluble. B group vitamins are water soluble. These vitamins must be supplied in our diet on a regular basis as they can be readily excreted in urine.

42. (b) Vitamins are always needed in the body & need to be taken with a balanced diet via outside source. They are not synthesised in our body but are excreted out regularly through urine.

43. (a) Lipase hydrolysis triglycerides to fatty acids and glycerol.

$$\text{Triglycerides} \xrightarrow{\text{Lipase}} \text{(3 molecule) fatty acid} + \text{glycerol (1-molecule)}$$

44. (b) Vitamin B_{12} is chemically named as cyanocobalamine having molecular formula $C_{63}H_{88}O_{14}N_{14}PCo$.

45. (b) Diastase is an enzyme. (The protein produced by living system which acts as a biological catalyst). They are named after the compound or class of compound upon which they work.

46. (a) The enzymes are globular proteins which catalyse chemical reactions in the living systems.

47. (b) Enzymes are highly specific both in binding chiral substrates and in catalysing their reactions. It fits like a key in the lock.

48. (c) Chemically considering, digestion is basically hydrolysis reaction in which hydrolysis of large molecules takes place to give smaller molecules.

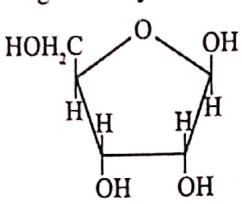
49. (b) Enzymes being biocatalyst increases the rate of a chemical reaction by providing alternative lower activation energy pathways.

50. (d) When nucleoside is linked to **phosphoric acid** at 5'-position of sugar moiety, we get nucleotide.

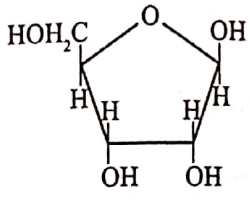
51. (c) In transcription process, the DNA sqeuence of a gene is copied which results in the formation of RNA molecule. In translation process, the sequence of m-RNA is decoded which is used to specify the sequence of amino acid of a polypeptide. The unidirectional flow of information is known as the central dogma.

$$\text{DNA} \xrightarrow{\text{Transcription}} \text{RNA} \xrightarrow{\text{Translation}} \text{Proteins}$$

52. (c) On complete hydrolysis of DNA or RNA, pentose sugar, phosphoric acid and nitrogen containing compounds known as bases are formed. In DNA molecules, β-D-2-dexoyribose is a sugar moiety while in RNA molecule, it is β-D-ribose.



β-D-ribose

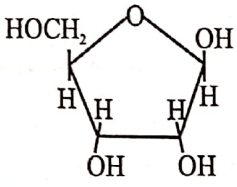


β-D-droxyribose

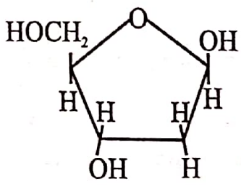
53. (b) Gene is the segment of DNA which acts as the instrumental manual for the synthesis of the protein. Every protein in a cell contains a corresponding gene.

54. (b) Complimentary base pairing in DNA takes place between C ≡ G with 3 H bonds & A = T with 2 H bonds.

55. (c) Each nucleic acid consists of a pentose sugar, a N-heterocyclic base and phosphoric acid. The sugar present in DNA is 2-deoxy-D(–) ribose sugar, in RNA, D (–)ribose sugar is present. The chirality of DNA and RNA molecules is due to the presence of sugar components.



D(-)-ribose



2-deoxy-D(-)-ribose

56. (c) Cell membranes are mainly composed of phospholiphids bilayer structure having embedded proteins and some carbohydrates.

57. (d) Three nucleotides make a codon in m-RNA to form amino acid. Adenine (A), Guanine (G), cytosine (C) & uracil (U), these base act in forms of triplet.

58. (b) Phospholipids may be regarded as derivatives of glycerol in which two of the hydroxyl group are esterified with fatty acids while the third is esterified with some derivatives of phosphoric acid.

59. (a) Chargaff's rule states that DNA from any cell of all organisms should contain 1 : 1 ratio of pyrimidine and purine bases.

Adenine (A) = Thymine (T)

& Guanine (G) ≡ Cytosine (C)

(a) Based on the chemical & physical evidences, DNA molecules is believed to be double right handed helix made up of two polypeptide chains round the same axis like a spiral staircase.

It has been suggested that in DNA helix, (A) adenine binds with (T) Thyamine with double bond and (G) Guanine binds with (C) Cytosine with triple bond, so, A = T, G ≡ C

(a) The number of molecules of ATP (adenosine tri-phosphate) produced in lipid metabolism of a molecule of palmitic is 130.

(a) DNA has a double helical structure. These helix contain polynucleotide chains and these chains are held together by hydrogen bond. In these polynucleotide chain of DNA, adenine has thymine opposite to it and guanine has cytosine opposite it.

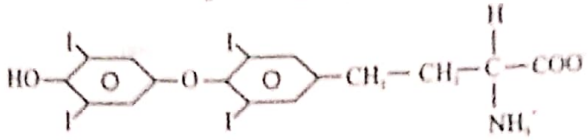
(a) Double helical structure of DNA: Double helix is composed of two right handed helical polynucleotide chains coiled around the same central axis. The two strands are antiparallel. The bases are stacked inside the helix in planes perpendicular to the helical axis. The two strands are held together by hydrogen bonds. Two hydrogen bonds between A and T (A = T) and three are formed between C and G (C ≡ G).

(c) Adrenaline hormone helps to release fatty acids from fat and glucose from liver glycogen under the condition of stress. Adrenaline hormone is produced by adrenal glands when a brain sends a message about a stressful situation. It is also known as 'flight of fight hormone'.

65. (c) Thyroxine is the main hormone which gets secreted into the bloodstream by the thyroid gland. It plays a significant role in digestion, brain development and in the maintenance of bones.

Thyroxine

66. (c) Thyroxine is an amine hormone and water soluble hormone containing amino group. Its structure is



67. (b) Glucagon is a single chain peptide of 29 amino acids, synthesised by the α-cells in the islets of langerhans of the pancreas.

68. (c) Insulin is a peptide hormone which is produced in pancrease and converts glucose to glycogen.

$$\text{Glucose} \xrightarrow{\text{insulin}} \text{Glycogen}$$

69. (a) It is a hormone secreted from thyroid gland. It controls various biochemical reactions involving burning of protein, carbohydrates, fats to release energy.

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CHAPTER 12

Principles Related to Practical Chemistry

Detection of Extra Elements

1. An organic compound which produces a bluish green coloured flame on heating in presence of copper is:
   a. benzaldehyde
   b. benzoic acid
   c. aniline
   d. chlorobenzene

2. Lassaigne's test (with silver nitrate) is commonly used to detect halogens such as chlorine, bromine and iodine but not useful to detect fluorine because the product AgF formed is:
   a. volatile
   b. reactive
   c. explosive
   d. soluble in water

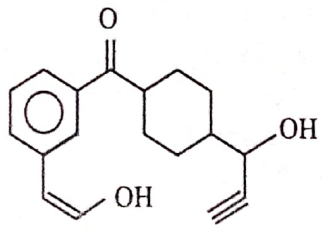
3. In the estimation of sulphur in an organic compound, fuming nitric acid is used to convert sulphur into:
   a. SO_2
   b. H_2S
   c. H_2SO_3
   d. H_2SO_4

4. **Assertion (A):** During test for nitrogen with Lassaigne extract on adding $FeCl_3$ solution, sometimes a red precipitate is formed.
   Reason (R): This indicates that sulphur is also present.
   a. If both Assertion and Reason are True and the Reason is the correct explanation of the Assertion.
   b. If both Assertion and Reason are True but Reason is not the correct explanation of the Assertion.
   c. If Assertion is True but the Reason is False.
   d. If Assertion is False but the Reason is True.

Detection of the Functional Groups

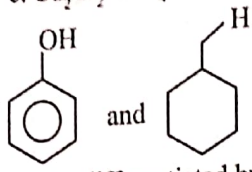
5. Which of the following is true?
   a. Tollen's reagent gives a positive test with all aldehyde
   b. Fehling's solution gives a positive test with all aldehyde
   c. Tollen's reagent gives a positive test with all carboxylic acid
   d. Tollen's reagent gives a positive test with a-methyl ketone

6.



Which of the following reagents will not react with abov compound?
a. Na metal
b. $AgNO_3 + NH_4OH$
c. $Cu_2Cl_2 + NH_4OH$
d. $NaHCO_3$

7.



can be differentiated by:
a. $FeCl_3$
b. NaOH
c. $NaNO_2 + HCl$
d. Fehling's solution

8. Match the column:

	Test		Detection of functional group
A.	Schiff's Test	p.	Carboxylic acid
B.	Litmus Test	q.	Phenol
C.	Liebermann nitroso test	r.	Halogen
D.	Beilstein Test	s.	Aldehyde

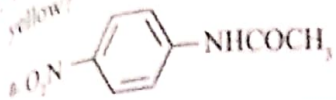
a. A-(q), B-(r), C-(s), D-(p)
b. A-(q), B-(s), C-(r), D-(p)
c. A-(r), B-(p), C-(s), D-(q)
d. A-(s), B-(p), C-(q), D-(r)

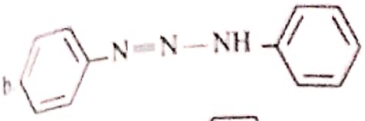
9. **Statement (I):** Phenols having free para position respon positively to Liebermann's nitroso test.
   Statement (II): Secondary amines give positive Liebermann test.
   a. Statement-I and Statement-II both are correct
   b. Statement-I and Statement-II both are incorrect
   c. Statement-I is correct and Statement-II is incorrect
   d. Statement-I is incorrect but Statement-II is correct

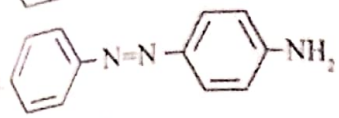
Preparation of Organic and Inorganic Compounds

10. What product is formed when aniline is treated wi CH_3COCl?
    a. Acetanilide
    b. Hydrazo benzene
    c. Phenol
    d. Para acetyl aniline

11. Which of the following is the molecular formula of aniline yellow?

a. 

b. 

c. 

d. None of these

12. How many water of crystallisation are in Mohr's salt?

a. 3 b. 2

c. 1 d. 6

Titration

13. Heat of neutralization will be maximum for:

	ACID (1 M)	Base (1M)
1.	30 mL HCl	70 mL NaOH
2.	40 mL HCl	60 mL NaOH
3.	20 mL HCl	80 mL NaOH
4.	80 mL HCl	20 mL NaOH

a. 1 b. 2

c. 3 d. 4

14. If 83 mL of 0.45 M NaOH solution neutralizes a 235 mL HCl solution. Calculate the molarity of the HCl solution.

a. 0.12 b. 0.16

c. 0.1 d. 0.2

15. Which of the following indicator should be used during titration of weak acid with a strong base?

a. Methyl orange b. Phenolphthalein

c. Bromothymol blue d. None of these

16. Aqueous solution of 6.3 gm oxalic acid of 250 ml is prepared. What volume of 0.1 N NaOH is required for neutralisation of 10 ml oxalic acid solution?

a. 20 mL b. 40 mL

c. 10 mL d. 30 mL

Preliminary/Wet Tests

17. In which of the following reactions a reddish-brown coloured gas is evolved?

a. $KBr\ (s) + conc.H_2SO_4 \longrightarrow$

b. $NH_4NO_2 \xrightarrow{\Delta}$

c. $NaNO_3 \xrightarrow[800°C]{\Delta}$

d. $Na_2S_2O_3 \longrightarrow NaI + ____$

18. Be and Mg do not impart colour to flame:

a. Due to very high IE.

b. Due to higher ionic potential

c. Due to their greater covalent character.

d. All of the above.

19. On heating, a white amorphous inorganic compound becomes yellow and on cooling, turns white again. The salt may be:

a. $PbCO_3$ b. $MgCO_3$

c. $ZnCO_3$ d. K_2CO_3

20. A brick red colour is imparted to Bunsen flame by a:

a. Ca salt b. Sr salt

c. Na salt d. Co salt

Dilute HCl/dil. H_2SO_4 Group

21. Two inorganic compounds A and B were heated in a dry test tube. A evolved a colourless gas which turned lead acetate paper black and B evolved a gas which turned lime water milky. The anions in A and B respectively are:

a. SO_3^{2-}, CO_3^{2-} b. S^{2-}, CO_3^{2-}

c. PO_4^{3-}, HCO_3^- d. S^{2-}, NO_3^-

22. The acidic solution of a salt produces blue colour with KI starch solution. The reaction indicates the presence of:

a. Sulphite b. Bromide

c. Nitrite d. Chloride

Concentrated HCl/Conc. H_2SO_4 Group

23. A solution of a salt in concentrated H_2SO_4 produced a deep blue colour with starch iodide solution. The salt may contain:

a. Chloride b. Carbonate

c. Acetate d. Bromide

24. Which of the following salts evolved brown fumes on treatment with conc. H_2SO_4?

a. Nitrate b. Bromide

c. Both d. None of these

25. Which of the following pair of anions are identified by conc. H_2SO_4?

a. NO_3^-, CO_3^{2-} b. Cl^-, NO_3^-

c. Br^-, CO_3^{2-} d. CO_3^{2-}

Precipitation Reactions

26. Precipitate of $PbSO_4$ is soluble in:

a. Ammonium acetate (6M) b. Dilute HCl

c. Dilute H_2SO_4 d. None of these

27. Which anion does not liberate any gas with dilute as well as conc. H_2SO_4?

a. NO_2^- b. NO_3^-

c. SO_3^{2-} d. SO_4^{2-}

Group I Radicals

28. Consider the following observation;

M^{n+} + HCl (dilute) $\longrightarrow$ white precipitate $\xrightarrow{\Delta}$ water soluble $\xrightarrow{CrO_4^{2-}}$ yellow precipitate.

The metal ion M^{n+} will be:

a. Hg^{2+} b. Ag^+

c. Pb^{2+} d. Sn^{2+}

29. A white powder when strongly heated gives off brown fumes. A solution of this powder gives a yellow precipitate with a solution of KI. When a solution of barium chloride is added to a solution of powder, a white precipitate results. This white powder may be:

a. A soluble sulphate b. KBr or NaBr

c. $Ba(NO_3)_2$ d. $AgNO_3$

30. A metal nitrate reacts with KI solution to give yellow precipitate which on addition of excess of more concentrated solution (6M) of KI dissolves forming a solution. The cation of metal nitrate is:

a. Hg_2^{2+} b. Ag^+

c. Pb^{2+} d. Cu^{2+}

Group II A Radicals

31. H_2S in the presence of HCl precipitates II group but not IV group because:

a. HCl activates H_2S.

b. HCl increases concentration of Cl^-.

c. HCl decreases concentration of S^{2-}.

d. HCl lowers the solubility of H_2S in solution.

32. Black sulphides is not formed by:

a. Cu^{2+} b. Sb^{3+}

c. Pb^{2+} d. Ag^+

Group III Radicals

33. An original solution of an inorganic salt in dilute HCl gives a brown colouration with potassium hexacyanidoferrate (III) and reddish brown colouration with sodium acetate solution. The cation of the salt is:

a. Ni^{2+} b. Fe^{3+}

c. Cu^{2+} d. None of these

34. To avoid the precipitation of hydroxides of Zn^{2+}, Mn^{2+} and Ni^{2+} along with those of Fe^{3+}, Al^{3+} and Cr^{3+}, the third group solution should be:

a. Concentrated HNO_3 is added.

b. Treated with excess of NH_4Cl.

c. Concentrated H_2SO_4 is added.

d. Treated with excess of NH_4OH.

35. $K_4[Fe(CN)_6] + Fe^{3+}$ (aq.) $\longrightarrow$ products;

Here products is/are:

a. $K_2Fe[Fe(CN)_6]$ b. $Fe[Fe(CN)_6]$

c. $Fe_3[Fe(CN)_6]_2$ d. $Fe_4[Fe(CN)_6]_3$

36. Which of the following statement is correct?

a. Fe^{3+} gives red colour with potassium thiocyanate

b. Fe^{3+} gives blue precipitate with potassium ferricyanide

c. Fe^{2+} gives brown colour with potassium ferrocyanide

d. Fe^{3+} gives pink colour with potassium ferrocyanide

Group IV Radicals

37. An aqueous solution of colourless metal sulphate M gives a white ppt, with NH_4OH. This is soluble in excess of NH_4OH. On passing H_2S through this solution a white ppt. is formed. The metal M in the salt is:

a. Ni b. Ba

c. Al d. Zn

38. The ion that can not be precipited by H_2S in presence of dil. HCl:

a. Pb^{2+} b. As^{3+}

c. Cu^{2+} d. Co^{2+}

Group V, VI and Zero Radicals

39. A metal salt solution form a yellow ppt with potassium chromate in acetic acid, a white ppt with dilute sulphuric acid but gives no ppt with sodium chloride or iodide. The white precipitate obtained when sodium carbonate is added to the metal salt solution will consist of:

a. Lead carbonate b. Basic lead carbonate

c. Barium Carbonate d. Strontium nitrate

40. Na_2CO_3 cannot be used in place of $(NH_4)_2CO_3$ for the precipitation of V group because:

a. NaI interferes in the detection of V group.

b. Conc. of CO_3^{2-} is very low.

c. Na will react with acid radicals.

d. Mg will be precipitated.

41. The brown precipitate formed by passing ammonia into Nessler's reagent in due to the formation of

a. HgI_4^{2-} b. $NH_2O–Hg–HgI$

c. $NH_2–Hg–O–Hg–I$ d. $NH_3–Hg–I$

Chemistry involved in Enthalpy Change, Formation of Colloid, and Reaction Kinetics in Chemical Processes

42. The heat of neutralisation of a strong dibasic acid in dilute solution by NaOH is nearly:

a. –27.4 kcal/eq
b. 13.7 kcal/eq
c. –13.7 kcal/eq
d. –13.7 kcal/mol

43. The enthalpy of solution of hydrated copper(II) sulfate can be determined by measuring the temperature changes when a known amount of copper(II) sulfate is added to a fixed volume of water in a calorimeter. What assumption is not made when calculating the enthalpy change?

a. There is negligible heat losses in the calorimeter
b. The specific heat capacity of the solution is the same as water
c. The density of solution is the same as water
d. The specific heat capacity of solution is different from water

44. For kinetic study of the reaction of iodide ion with H_2O_2 at room temperature:

A. Always use freshly prepared starch solution.
B. Always keep the concentration of sodium thiosulphate solution less than that of KI solution.
C. Record the time immediately after the appearance of blue colour.
D. Record the time immediately before the appearance of blue colour.
E. Always keep the concentration of sodium thiosulphate solution more than that of KI solution.

Choose the correct answer from the options given below:

a. A, B, C only
b. A, D, E only
c. D, E only
d. A, B, E only

45. Match the items given in Column-I and Column-II.

Column-I		Column-II	
A.	Protective colloid	p.	$FeCl_3$ + NaOH
B.	Liquid-liquid colloid	q.	Lyophilic colloids
C.	Positively charged colloid	r.	Emulsion
D.	Negatively charged colloid	s.	$FeCl_3$ + hot water

a. A-(r), B-(r, s), C-(q), D-(p)
b. A-(q,s), B.-(q), C-(r), D-(p)
c. A-(q), B-(r), C-(s), D-(p)
d. A-(s), B-(r), C-(p), D-(q)

Answer Key

1. (d)	2. (d)	3. (d)	4. (b)	5. (a)	6. (d)	7. (a)	8. (d)	9. (a)	10. (a)
11. (c)	12. (d)	13. (b)	14. (b)	15. (b)	16. (b)	17. (a)	18. (a)	19. (c)	20. (a)
21. (b)	22. (c)	23. (d)	24. (c)	25. (b)	26. (a)	27. (d)	28. (c)	29. (d)	30. (c)
31. (c)	32. (b)	33. (b)	34. (b)	35. (d)	36. (a)	37. (d)	38. (d)	39. (c)	40. (d)
41. (c)	42. (c)	43. (d)	44. (a)	45. (c)					

Explanations

1. (d) An organic compound which produces a bluish green flame when heated on a copper wire is chlorobenzene. This is called Beilstein's test and this test is used to detect the presence of halogen in an organic compound. Green color of the flame is due to the formation of copper halide.

2. (d) AgF is highly soluble in H_2O therefore, NaF formed in the Lassaigne's extract does not produce a ppt. with $AgNO_3$.

3. (d) Estimation of Sulphur: In this method, a known quantity of organic compounds is heated with either fuming nitric acid or sodium peroxide in a hard glass tube called the Carius tube. Sulphur present in the compound is oxidized to form sulphuric acid.

4. **(b)** On adding $FeCl_3$ solution to sodium extract during testing for nitrogen a red precipitate is obtained. It is due to the presence of sulphur also.

$$3NaCNS + FeCl_3 \rightarrow \underset{\text{Red colour}}{Fe(CNS)_3} + 3NaCl$$

5. **(a)** Tollen's reagent gives a positive test with all aldehydes. Tollen's reagent oxidizes an aldehyde into the corresponding carboxylic acid. Fehling's test is used to distinguish aldehydes from ketones and aliphatic aldehydes from aromatic aldehydes.

6. **(d)** $NaHCO_3$ will not react with the given compound, because $NaHCO_3$ reacts with strong acidic groups.

Aniline yellow
(p-Aminoazobenzene)

12. **(d)** Mohr's salt contains 6 molecules of water. Ferrous ammonium sulphate is called Mohr's salt.

Molecular formula of Mohr's salt is $FeSO_4.(NH_4)_2SO_4.6H_2O$. It is a double salt of ammonium sulphate and iron sulphate.

13. **(b)** First, 30 mL HCl is neutralized by 70 mL NaOH. But HCl is the limiting factor here so, overall 30 mL neutralization takes place.

In the 2nd, 40 mL HCl is neutralized by 60 mL NaOH. But HCl is the limiting factor here, so overall 40 mL neutralization takes place.

In the 3rd, 20 mL HCl is neutralized by 80 mL NaOH. But HCl is the limiting factor here so, overall 20 mL neutralization takes place.

In 4th, 80 mL HCl is neutralized by 20 mL NaOH. NaOH is the limiting factor here so, overall 20 mL neutralization takes place.

Heat of neutralization will be more for reaction of 40 mL HCl and 60 mL NaOH.

14. **(b)** $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(\ell)$

From the molarity equation: M_AV_A/n_A (acid) $= M_BV_B/n_B$ (base)

Hence, $M_A = M_BV_Bn_A/n_BV_A = 0.45M \times 83$ mL $\times$ 1/235 mL $\times$ $1 = 0.16M$

The molarity of the HCl solution is 0.16M.

15. **(b)** Phenolphthalein is an indicator used for titrations of a weak acid and strong base, and itself is a weak acid. The weak acid is colorless and its ion is bright pink. It distinguishes the pH range from 8 to 9.6. Adding extra hydrogen ions shifts the position of equilibrium to the left, and turns the indicator colorless. Adding hydroxide ions removes the hydrogen ions from the equilibrium which shifts to the right to replace them - turning the indicator pink.

Methyl orange, Methyl red are used for the titration of strong acid and strong base or strong acid and weak base while Bromothymol blue is a dye used as an indicator in determining pH. Bromthymol blue is a weak acid. It can be in acid or base form, depending on the pH of the solution.

18. **(a)** Be and Mg ionization energies when compared to other alkaline earth metals. The energy of flame is not sufficient to excite the electrons of Be and Mg to higher energy levels. Hence, Be and Mg do not give any color in bunsen flame.

19. **(c)** Pure $ZnCO_3$ is a white powder crystalline. Zinc oxide is thermochromic, changing from white to yellow when heated in air and reverting to white on cooling.

$$\underset{\text{White}}{ZnCO_3} \xrightarrow{\Delta} \underset{\text{Yellow}}{ZnO} + CO_2\uparrow$$

20. **(a)** The brick's red colour is produced by calcium metal in flame. It is caused by the thermal energy's excitation of electrons, which is followed by the de-excitation of an electron to its ground state and the release of visible light.

21. **(b)** A contains S^{2-} and B contains CO_3^{2-}

$$\underset{(A)}{S^{2-}} \xrightarrow{\Delta} H_2S \xrightarrow{Pb(CH_3COO)_2} \underset{\text{Black PPt.}}{PbS\downarrow}$$

$$\underset{(B)}{CO_3^{2-}} \xrightarrow{\Delta} CO_2 \xrightarrow{Ca(OH)_2} \underset{\text{White turbidity}}{CaCO_3}$$

22. **(c)** Confirmatory test: Nitrites react with potassium iodide in the presence of dilute sulphuric acid to liberate iodine. Iodine forms a blue-black complex with starch.

$$2KI + 2H_2SO_4 + 2HNO_2 \rightarrow 2KHSO_4 + \underset{\text{Iodine}}{I_2} + 2NO + 2H_2O$$

I_2 + starch $\rightarrow$ Blue-black complex.

23. **(d)** The salt is a bromide salt. When it reacts with concentrated sulphuric acid, bromine gas is released which turns starch containing potassium iodide blue.

$$Br^- + 2H_2SO_4 \rightarrow Br_2\downarrow + SO_2 + SO_4^{2-} + H_2O$$

$$2I^- + Br_2 \rightarrow 2Br^- + I_2\downarrow$$

I_2 + starch $\rightarrow$ blue colour solution

24. **(c)** Nitrate and bromide both give brown fumes when added H_2SO_4.

25. **(b)** Concentrated acid group: NO_3^-, CH_3COO^-, Cl^-, Br^-, I^-.

26. **(a)** Solubility of $PbSO_4$ in Ammonium acetate:

When $PbSO_4$ is added to a solution of ammonium acetate, the acetate ions form soluble complexes with Pb^{2+} ions.

The complexation reaction is:

$AgNO_3 \rightarrow Ag + NO_2 + \frac{1}{2}O_2$

$AgNO_3 + KI \rightarrow AgI + KNO_3$;

$BaCl_2 + 2AgNO_3 \rightarrow 2AgCl + Ba(NO_3)_2$

30. (c)

$Pb(NO_3)_2 \xrightarrow{KI} \underset{\text{(Yellow)}}{PbI_2} \xrightarrow[\text{Excess}]{KI(>6M)} \underset{\text{(Soluble)}}{[PbI_4]^{2-}}$

$\uparrow$ Dilution

31. (c) In presence of HCl, H_2S results the precipitation of group-2 elements but not group-4 elements due to lower concentration of S^{2-} ion.

32. (b) Sb^{+3} does not form black color sulphide.

33. (b) $Fe^{3+} + [Fe(CN)_6]^{3-} \rightarrow Fe[Fe(CN)_6]$ brown colouration

$3Fe^{+3} + 6CH_3COO^- + 2H_2O \Leftrightarrow [Fe_3(OH)_2(CH_3COO)_6]^+ + 2H^+$

34. (b) The third group solution should be treated with excess of NH_4Cl. The presence of NH_4Cl in excess reduces degree of dissociation of NH_4OH to a considerable amount, and thus, $[OH^-]$ is just sufficient to cross over the ionic concentration product of hydroxides of III group elements to their K_{sp}.

35. (d) $4FeCl_3 + 3K_4(Fe(CN)_6) \rightarrow Fe_4(Fe(CN)_6)_3 + 12KCl$

36. (a) • fFe^{3+} gives a red colour with potassium thiocyanate

$Fe^{3+} + SCN^- \rightarrow [Fe(SCN)]^{2+}$

Blood red colour

• Fe^{3-} gives blue precipitate with potassium ferrocyanide and Fe^{2-} gives blue precipitate with potassium ferricyanide.

$4FeCl_3 + 3K_4[Fe(CN)_6] \rightarrow Fe_4[Fe(CN)_6]_3 + 12KCl$

Potassium ferrocyanide — Prussian blue precipitate

dil HCl as dil HCl will suppress the ionization of H_2S.

To affect the precipitation, H_2S should be used in the ammoniacal solution.

39. (c) Pb and Ba both give yellow ppt with K_2CrO_4 in acetic and white precipitate with dil. H_2SO_4. But lead salts give a precipitate with sodium chloride or iodide also whereas barium does not. It means given salt is barium salts and with sodium carbonate, it gives a white precipitate of barium carbonate.

40. (d) Na_2CO_3 furnishes appreciable CO_3^{2-} to precipitate Mg.

41. (c) Nessler's reagent is an alkaline solution of Potassium tetraiodomercurate(II)- $K_2[HgI_4]$.

On being passed through a solution of ammonia, it gives a dirty brown precipitate. The reaction involved is:

$2K_2[HgI_4] + 3KOH + NH_3 \rightarrow H_2N.HgO.HgI + 7KI + 2H_2O$

H_2N-Hg-O-Hg-I is called Iodide of Million's base which is an insoluble dirty brown precipitate. It is also used in test for ammonium ion.

42. (c) The enthalpy of neutralisation of strong acid and strong base is constant, i.e., -13.7 kcal eq^{-1}

43. (d) The specific heat capacity of water is used to calculate the heat absorbed or released by the solution. If the specific heat capacity of the solution were different, the calculated enthalpy change would be inaccurate.

44. (a) The correct options for the kinetic study of the reaction of the iodide ion with H_2O_2 at room temperature are (A), (B), and (C). The time is recorded immediately after the blue colour appears, and sodium thiosulfate is kept in a limited amount.

45. (c)

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Section-A

Some Basic Concepts of Chemistry

(Stoichiometry and Stoichiometric Calculations)

1. 1 gram of sodium hydroxide was treated with 25 mL of 0.75 M HCl solution, the mass of sodium hydroxide left unreacted is equal to

a. Zero mg
b. 200 mg
c. 750 mg
d. 250 mg

(Mole Concept and Molar Masses)

2. The highest number of helium atoms is in

a. 4 g of helium
b. 2.271098 L of helium at STP
c. 4 mol of helium
d. 4 u of helium

Structure of Atom

(Bohr's Model for Hydrogen Atom)

3. The energy of an electron in the ground state (n = 1) for He^+ ion is –xJ, then that for an electron in n = 2 state for Be^{3+} ion in J is:

a. $-4x$
b. $-\frac{4}{9}x$
c. $-x$
d. $-\frac{x}{9}$

(Quantum Mechanical Model of Atom)

4. Match List I with List II.

List I Quantum Number		List II Information provided	
A.	m_l	I.	shape of orbital
B.	m_s	II.	size of orbital
C.	l	III.	orientation of orbital
D.	n	IV.	orientation of spin of electron

Choose the correct answer from the options given below:

a. A-III, B-IV, C-II, D-I
b. A-II, B-I, C-IV, D-III
c. A-I, B-III, C-II, D-IV
d. A-III, B-IV, C-I, D-II

Classification of Elements and Periodicity in Properties

(Periodic Trends in Properties of Elements)

5. Arrange the following elements in increasing order of electronegativity:

N, O, F, C, Si

Choose the correct answer from the options given below:

a. O < F < N < C < Si
b. F < O < N < C < Si
c. Si < C < N < O < F
d. Si < C < O < N < F

6. Arrange the following elements in increasing order of first ionization enthalpy:

Li, Be, B, C, N

Choose the correct answer from the options given below:

a. Li < Be < C < B < N
b. Li < Be < N < B < C
c. Li < Be < B < C < N
d. Li < B < Be < C < N

Chemical Bonding and Molecular Structure

(VSEPR Theory)

7. Match List I with List II.

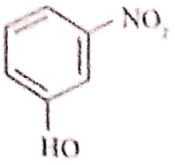
List I (Compound)		List II (Shape/geometry)	
A.	NH_3	I.	Trigonal Pyramidal
B.	BrF_5	II.	Square Planar
C.	XeF_4	III.	Octahedral
D.	SF_6	IV.	Square Pyramidal

Choose the correct answer from the options given below:

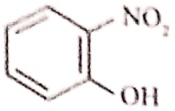
a. A-III, B-IV, C-I, D-II
b. A-II, B-III, C-IV, D-I
c. A-I, B-IV, C-II, D-III
d. A-II, B-IV, C-III, D-I

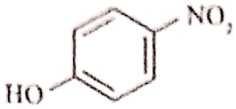
(Hydrogen Bonds)

8. Intramolecular hydrogen bonding is present in

a. 

b. HF

c. 

d. 

Thermodynamics

(Thermodynamics Terms)

9. Match List I with List II.

List I (Process)		List II (Conditions)	
A.	Isothermal process	I.	No heat exchange
B.	Isochoric process	II.	Carried out at constant temperature
C.	Isobaric process	III.	Carried out at constant volume
D.	Adiabatic process	IV.	Carried out at constant pressure

Choose the correct answer from the options given below:

a. A-I, B-II, C-III, D-IV
b. A-II, B-III, C-IV, D-I
c. A-IV, B-III, C-II, D-I
d. A-IV, B-II, C-III, D-I

(Spontaneity, Entropy, Gibbs Energy Change and Equilibrium

10. In which of the following processes entropy increases?

A. A liquid evaporates to vapour

B. Temperature of a crystalline solid lowered from 130K to 0 K.

C. $2\,NaHCO_{3(s)} \rightarrow Na_2CO_{3(s)} + CO_{2(g)} + H_2O_{(g)}$

D. $Cl_{2(g)} \rightarrow 2\,Cl_{(g)}$

Choose the correct answer from the options given below:

a. A, C and D
b. C and D
c. A and C
d. A, B and D

Equilibrium

(Law of Chemical Equilibrium, Equilibrium Const. and Its Application)

11. For the reaction $2A \rightleftharpoons B + C$, $K_c = 4 \times 10^{-3}$. At a given time, the composition of reaction mixture is:

$[A] = [B] = [C] = 2 \times 10^{-3}$ M.

Then, which of the following is correct?

a. Reaction has a tendency to go in backward direction.
b. Reaction has gone to completion in forward direction.
c. Reaction is at equilibrium.
d. Reaction has a tendency to go in forward direction.

12. In which of the following equilibria, K_p and K_c are NOT equal?

a. $CO_{(g)} + H_2O_{(g)} \rightleftharpoons CO_{2(g)} + H_{2(g)}$
b. $2BrCl_{(g)} \rightleftharpoons Br_{2(g)} + Cl_{2(g)}$
c. $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$
d. $H_{2(g)} + I_{2(g)} \rightleftharpoons 2\,HI_{(g)}$

Redox Reactions

(Redox Reactions (Oxidation and Reduction), Oxidation Number)

13. Which reaction is NOT a redox reaction?

a. $H_2 + Cl_2 \rightarrow 2\,HCl$
b. $BaCl_2 + Na_2SO_4 \rightarrow BaSO_4 + 2\,NaCl$
c. $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$
d. $2\,KClO_3 + I_2 \rightarrow 2\,KIO_3 + Cl_2$

Organic Chemistry-Some Basic Principles and Techniques

(Classification, Nomenclature of Organic Compounds)

14. A compound with a molecular formula of C_6H_{14} has two tertiary carbons. Its IUPAC name is:

a. 2,3-dimethylbutane
b. 2,2-dimethylbutane
c. n-hexane
d. 2-methylpentane

(Tetravalence of Carbon (Shapes of Organic Compounds))

15. Match List I with List II.

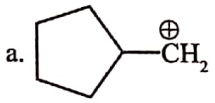
List I (Molecule)		List II (Number and types of bonds between two carbon atoms)	
A.	ethane	I.	one σ-bond and two π-bonds
B.	ethene	II.	two π-bonds
C.	carbon molecule, C_2	III.	one σ-bond
D.	ethyne	IV.	one σ-bond and one π-bond

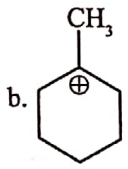
Choose the correct answer from the options given below:

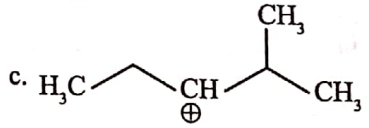
a. A-III, B-IV, C-II, D-I
b. A-III, B-IV, C-I, D-II
c. A-I, B-IV, C-II, D-III
d. A-IV, B-III, C-II, D-I

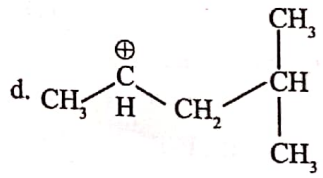
(Fundamental Concepts of Organic Reactions)

16. The most stable carbocation among the following is:

a. 

b. 

c. 

d. 

(Methods of Purification, Qualitative and Quantitative Analysis of Organic Compounds)

17. On heating some solid substances change from solid to vapour state without passing through liquid state. The technique used for the purification of such solid substances based on the above principle is known as

a. Distillation
b. Chromatography
c. Crystallization
d. Sublimation

Hydrocarbons

(Alkanes)

18. Given below are two statements:

Statement I: The boiling point of three isomeric pentanes follows the order

n-pentane > isopentane > neopentane

Statement II: When branching increases, the molecule attains a shape of sphere. This results in smaller surface area for contact, due to which the intermolecular forces between the spherical molecules are weak, thereby lowering the boiling point.

In the light of the above statements, choose the *most appropriate* answer from the options given below:

a. Statement I is correct but Statement II is incorrect.
b. Statement I is incorrect but Statement II is correct.
c. Both Statement I and Statement II are correct.
d. Both Statement I and Statement II are incorrect.

Solutions

(Solubility)

19. The Henry's law constant (K_H) values of three gases (A, B, C) in water are 145, 2×10^{-5} and 35 kbar, respectively. The solubility of these gases in water follow the order:

a. A > C > B
b. A > B > C
c. B > A > C
d. B > C > A

Electrochemistry

(Electrolytic Cells and Electrolysis)

20. Match List I with List II.

	List I (Conversion)		List II (Number of Faraday required)
A.	1 mol of H_2O to O_2	I.	3F
B.	1 mol of MnO_4^- to Mn^{2+}	II.	2F
C.	1.5 mol of Ca from molten $CaCl_2$	III.	1F
D.	1 mol of FeO to Fe_2O_3	IV.	5F

Choose the correct answer from the options given below:

a. A-II, B-III, C-I, D-IV
b. A-III, B-IV, C-II, D-I
c. A-II, B-IV, C-I, D-III
d. A-III, B-IV, C-I, D-II

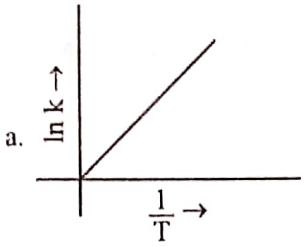
Chemical Kinetics

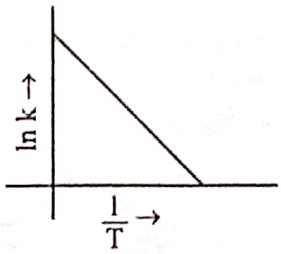
(Temperature Dependence of the Rate of a Reaction & Effect of Catalysts)

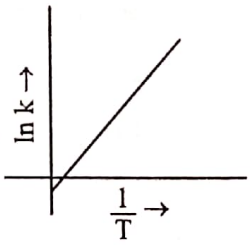
21. Activation energy of any chemical reaction can be calculated if one knows the value of

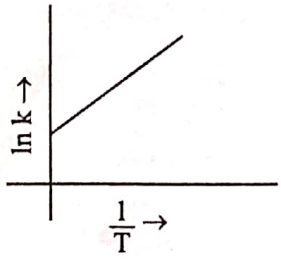
a. orientation of reactant molecules during collision
b. rate constant at two different temperatures
c. rate constant at standard temperature
d. probability of collision

22. Which plot of ln k vs $\frac{1}{T}$ is consistent with Arrhenius equation?

a. 

b. 

c. 

d. 

The p-Block Elements (Group 15 to 18)

(Group 16 Elements (Oxygen Family))

23. Given below are two statements:

Statement I: The boiling point of hydrides of Group 16 elements follow the order

$H_2O > H_2Te > H_2Se > H_2S$.

Statement II: On the basis of molecular mass, H_2O is expected to have lower boiling point than the other members of the group but due to the presence of extensive H-bonding in H_2O, it has higher boiling point.

In the light of the above statements, choose the *correct* answer from the options given below:

a. Statement I is true but Statement II is false.
b. Statement I is false but Statement II is true.
c. Both Statement I and Statement II are true.
d. Both Statement I and Statement II are false.

24. Among Group 16 elements, which one does **NOT** show –2 oxidation state?

a. Te
b. Po
c. O
d. Se

The d- and f-Block Elements

(Transition Elements (d-Block))

25. The E° value for the Mn^{3+}/Mn^{2+} couple is more positive than that of Cr^{3+}/Cr^{2+} or Fe^{3+}/Fe^{2+} due to change of

a. d^4 to d^5 configuration b. d^5 to d^6 configuration

c. d^5 to d^6 configuration d. d^6 to d^7 configuration

26. 'Spin only' magnetic moment is same for which of the following ions?

A. Ti^{3+}

B. Cr^{2+}

C. Mn^{2+}

D. Fe^{2+}

E. Sc^{3+}

Choose the most appropriate answer from the options given below:

a. B and C only b. A and D only

c. B and D only d. A and E only

Coordination Compounds

(Nomenclature & Isomerism in Coordination Compounds)

27. Match List-I with List-II.

	List-I (Complex)		List-II (Type of isomerism)
A.	$[Co(NH_3)_5(NO_2)]Cl_2$	I.	Solvate isomerism
B.	$[Co(NH_3)_5(SO_4)]Br$	II.	Linkage isomerism
C.	$[Co(NH_3)_6][Cr(CN)_6]$	III.	Ionization isomerism
D.	$[Co(H_2O)_6]Cl_3$	IV.	Coordination isomerism

Choose the correct answer from the options given below:

a. A-I, B-IV, C-III, D-II

b. A-II, B-IV, C-III, D-I

c. A-II, B-III C-IV, D-I

d. A-I, B-III, C-IV, D-II

(Bonding in Coordination Compounds)

28. Given below are two statements:

Statement I: Both $[Co(NH_3)_6]^{3+}$ and $[CoF_6]^{3-}$ complexes are octahedral but differ in their magnetic behaviour.

Statement II: $[Co(NH_3)_6]^{3+}$ is diamagnetic whereas $[CoF_6]^{3-}$ is paramagnetic.

In the light of the above statements, choose the *correct* answer from the options given below:

a. Statement I is true but Statement II is false.

b. Statement I is false but Statement II is true.

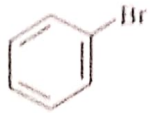
c. Both Statement I and Statement II are true.

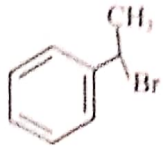
d. Both Statement I and Statement II are false.

Haloalkanes and Haloarenes

(Haloarenes and Chemical Reactions of Haloarenes)

29. The compound that will undergo S_N1 reaction with the fastest rate is

a. 

b. 

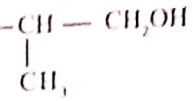
c.

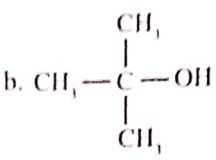
d.

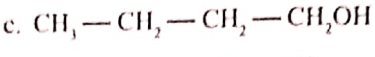
Alcohols, Phenols and Ethers

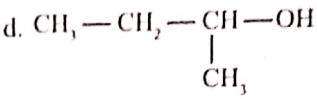
(Alcohols)

30. Which one of the following alcohols reacts instantaneously with Lucas reagent?

a. 

b. 

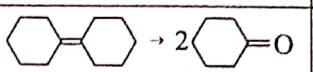
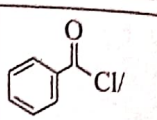
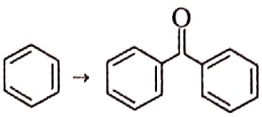
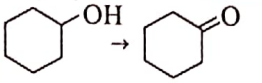
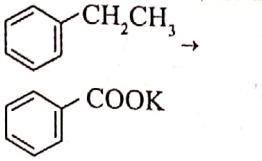
c. 

d. 

Aldehydes, Ketones and Carboxylic Acids

(Preparation of Aldehydes and Ketones)

31. Match List I with List II.

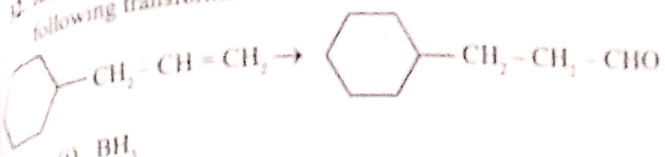
	List I (Reaction)		List II (Reagents/Condition)
A.		I.	 Anhyd.$AlCl_3$
B.		II.	CrO_3
C.		III.	$KMnO_4/KOH, \Delta$
D.		IV.	(i) O_3 (ii) Zn-H_2O

Choose the correct answer from the options given below:

a. A-IV, B-I, C-II, D-III b. A-I, B-IV, C-II, D-III

c. A-IV, B-I, C-III, D-II d. A-III, B-I, C-II, D-IV

32. Identify the correct reagents that would bring about the following transformation



a. (i) BH_3
(ii) $H_2O_2/\overset{\ominus}{O}H$
(iii) alk. $KMnO_4$
(iv) $H_3O^{\oplus}$

b. (i) H_2O/H^+
(ii) PCC

c. (i) H_2O/H^+
(ii) CrO_3

d. (i) BH_3
(ii) $H_2O_2/\overset{\ominus}{O}H$
(iii) PCC

(Physical Properties and Chemical Reactions of Aldehydes and Ketones)

33. Fehling's solution 'A' is

a. alkaline solution of sodium potassium tartrate (Rochelle's salt)
b. aqueous sodium citrate
c. aqueous copper sulphate
d. alkaline copper sulphate

Amines

(Physical & Chemical Properties of Amines)

34. Given below are two statements:

Statement I: Aniline does not undergo Friedel-Crafts alkylation reaction.

Statement II: Aniline cannot be prepared through Gabriel synthesis.

In the light of the above statements, choose the correct answer from the options given below:

a. Statement I is correct but Statement II is false.
b. Statement I is incorrect but Statement II is true.
c. Both Statement I and Statement II are true.
d. Both Statement I and Statement II are false.

Biomolecules

(Carbohydrates)

35. The reagents with which glucose does **not** react to give the corresponding tests/products are

A. Tollen's reagent
B. Schiff's reagent
C. HCN
D. NH_2OH
E. $NaHSO_3$

Choose the correct options from the given below:

a. B and E
b. E and D
c. B and C
d. A and D

Section-B

Some Basic Concepts of Chemistry

(Percentage Composition, Empirical & Molecular Formula)

36. A compound X contains 32% of A, 20% of B and remaining percentage of C. Then, the empirical formula of X is:
(Given atomic masses of A = 64; B = 40; C = 32u)

a. AB_2C_2
b. ABC_4
c. A_2BC_2
d. ABC_3

Chemical Bonding and Molecular Structure

(Bond Parameters and Dipole moment)

37. Identify the correct answer.

a. Dipole moment of NF_3 is greater than that of NH_3.
b. Three canonical forms can be drawn for CO_3^{2-} ion
c. Three resonance structures can be drawn for ozone.
d. BF_3 has non-zero dipole moment.

Thermodynamics

(Measurement of ΔU & ΔH, Work Done and Heat Capacity)

38. The work done during reversible isothermal expansion of one mole of hydrogen gas at 25 °C from pressure of 20 atmosphere to 10 atmosphere is:
(Given R = 2.0 cal K^{-1} mol^{-1})

a. 413.14 calories
b. 100 calories
c. 0 calorie
d. – 413.14 calories

Equilibrium

(Ionization of Acids & Bases, pH Scale, Hydrolysis)

39. Consider the following reaction in a sealed vessel at equilibrium with concentrations of $N_2 = 3.0 \times 10^{-3}$ M, $O_2 = 4.2 \times 10^{-3}$ M and $NO = 2.8 \times 10^{-3}$ M .

$2NO_{(g)} \rightleftharpoons N_{2(g)} + O_{2(g)}$

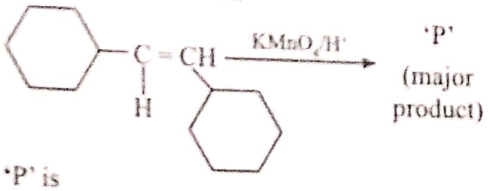
If 0.1 mol L^{-1} of $NO_{(g)}$ is taken in a closed vessel, what will be degree of dissociation (α) of $NO_{(g)}$ at equilibrium ?

a. 0.8889
b. 0.717
c. 0.00889
d. 0.0889

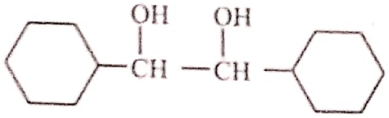
Hydrocarbons

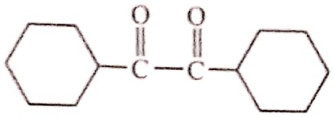
(Alkenes)

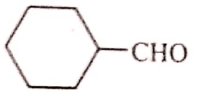
40. For the given reaction

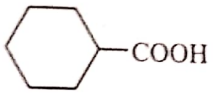


'P' is

a. 

b. 

c. 

d. 

Solutions

(Colligative Properties and Determination of Molar Mass)

41. The plot of osmotic pressure (Π) vs concentration (mol L^{-1}) for a solution gives a straight line with slope 25.73 L bar mol^{-1}. The temperature at which the osmotic pressure measurement is done is:

(Use R = 0.083 L bar mol^{-1} K^{-1})

a. 25.73°C
b. 12.05°C
c. 37°C
d. 310°C

Electrochemistry

(Electrolytic Cells and Electrolysis)

42. Mass in grams of copper deposited by passing 9.6487 A current through a voltmeter containing copper sulphate solution for 100 seconds is:

(Given : Molar mass of Cu: 63 g mol^{-1}, 1 F = 96487 C)

a. 31.5 g
b. 0.0315 g
c. 3.15 g
d. 0.315 g

Chemical Kinetics

(Temperature Dependence of the Rate of a Reaction & Effect of Catalysts)

43. The rate of a reaction quadruples when temperature changes from 27°C to 57°C. Calculate the energy of activation.

Given R = 8.314J K^{-1} mol^{-1}, log 4 = 0.6021

a. 3.80 kJ/mol
b. 3804 kJ/mol
c. 38.04 kJ/mol
d. 380.4 kJ/mol

The d- and f-Block Elements

(Inner Transition Elements (Lanthanoids and Actinoids))

44. The pair of lanthanoid ions which are diamagnetic is

a. Gd^{3+} and Eu^{3+}
b. Pm^{3+} and Sm^{3+}
c. Ce^{4+} and Yb^{2+}
d. Ce^{3+} and Eu^{2+}

Coordination Compounds

(Introduction and Werner's Theory of Coordination Compounds)

45. Given below are two statements:

Statement I: $[Co(NH_3)_6]^{3+}$ is a homoleptic complex whereas $[Co(NH_3)_4Cl_2]^{+}$ is a heteroleptic complex.

Statement II: Complex $[Co(NH_3)_6]^{3+}$ has only one kind of ligands but $[Co(NH_3)_4Cl_2]^{+}$ has more than one kind of ligands.

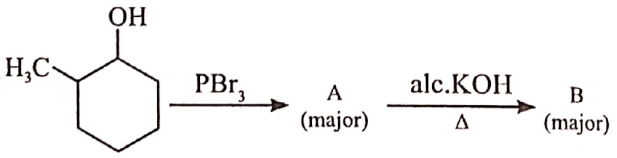
In the light of the above statements, choose the correct answer from the options given below:

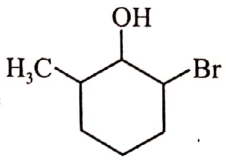
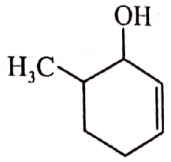
a. Statement I is true but Statement II is false.
b. Statement I is false but Statement II is true.
c. Both Statement I and Statement II are true.
d. Both Statement I and Statement II are false.

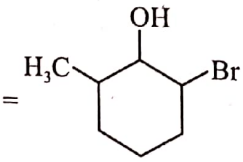
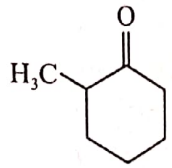
Haloalkanes and Haloarenes

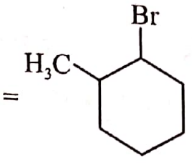
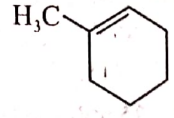
(Haloalkanes and Chemical Reactions of Haloalkanes)

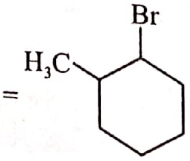
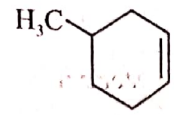
46. Major products A and B formed in the following reaction sequence, are



a. A =  ; B = 

b. A =  ; B = 

c. A =  ; B = 

d. A =  ; B = 

Alcohols, Phenols and Ethers

(Alcohols)

47. The products A and B obtained in the following reactions, respectively, are

$3ROH + PCl_3 \rightarrow 3RCl + A$

$ROH + PCl_5 \rightarrow RCl + HCl + B$

a. H_3PO_4 and $POCl_3$ b. H_3PO_3 and $POCl_3$

c. $POCl_3$ and H_3PO_3 d. $POCl_3$ and H_3PO_4

Amines

(Preparation of Amines)

48. Identify the major product C formed in the following reaction sequence:

$$CH_3-CH_2-CH_2-I \xrightarrow{NaCN} A$$

$$\xrightarrow[\text{Partial hydrolysis}]{OH} B \xrightarrow[Br_2]{NaOH} \underset{\text{major}}{C}$$

a. butanamide b. α-bromobutanoic acid

c. propylamine d. butylamine

Principle Related to Practical Chemistry

(Preparation of Organic and Inorganic Compounds)

49. During the preparation of Mohr's salt solution (Ferrous ammonium sulphate), which of the following acid is added to prevent hydrolysis of Fe^{2+} ion?

a. dilute nitric acid

b. dilute sulphuric acid

c. dilute hydrochloric acid

d. concentrated sulphuric acid

(Qualitative Analysis of Inorganic Salts)

50. Given below are certain cations. Using inorganic qualitative analysis, arrange them in increasing group number from 0 to VI.

A. Al^{3+} B. Cu^{2+}

C. Ba^{2+} D. Co^{2+}

E. Mg^{2+}

Choose the correct answer from the options given below:

a. E, C, D, B, A b. E, A, B, C, D

c. B, A, D, C, E d. B, C, A, D, E

Answer Key

1. (d)	2. (c)	3. (c)	4. (d)	5. (c)	6. (d)	7. (c)	8. (c)	9. (b)	10. (a)
11. (a)	12. (c)	13. (b)	14. (a)	15. (a)	16. (b)	17. (d)	18. (c)	19. (d)	20. (c)
21. (b)	22. (b)	23. (c)	24. (b)	25. (c)	26. (c)	27. (c)	28. (c)	29. (b)	30. (b)
31. (a)	32. (d)	33. (c)	34. (c)	35. (a)	36. (d)	37. (b)	38. (d)	39. (b)	40. (d)
41. (c)	42. (d)	43. (c)	44. (c)	45. (c)	46. (c)	47. (b)	48. (c)	49. (b)	50. (c)

Explanations

1. (d) $NaOH + HCl \rightarrow NaCl + H_2O$

Mass of NaOH = 1 g

Moles of NaOH = $\frac{1}{40}$ moles

= 0.025 moles

= 25 millimoles

Millimoles of HCl = M × V = 25 × 0.75

= 18.75 millimoles

Millimoles of NaOH unreacted

= 25 – 18.75

= 6.25 millimoles

Mass = 40 × 6.25 = 250 mg

2. (c)

- Atoms in 4 g of Helium $= \frac{4}{4} \times N_A = N_A$
- Atoms in 2.271098 L of Helium at STP $= \frac{2.271098}{22.4} \times N_A$ $= 0.101\ N_A$
- Atoms in 4 mol of Helium $= 4 \times N_A = 4N_A$
- Atoms in 4u of Helium $= \frac{4}{4} = 1$

Hence, highest number of atoms are present in 4 mol of Helium.

3. (c)

- For He^+ ion; Energy = –x J, Z = 2, n = 1

$$\text{Energy} = \frac{-2.18 \times 10^{-18} Z^2}{n^2} J$$

$$-x = \frac{-2.18 \times 10^{-18} \times (2)^2}{(1)^2} J$$

$$x = 2.18 \times 10^{-18} \times 4\ J$$

O = 3.5
N = 3.0 } electronegativity
C = 2.5
Si = 1.8

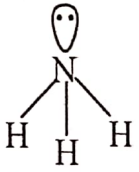
Hence order will be:

$Si < C < N < O < F$

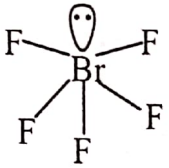
6. (d)

- In a period, generally on moving left to right ionization enthalpy increases. But due to more stable configuration of $Be(2s^2)$, its ionization enthalpy is more as compared to $B(2p^1)$, less stable configuration.
- So, correct order of first IE : $Li < B < Be < C < N$

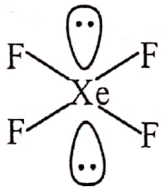
7. (c)



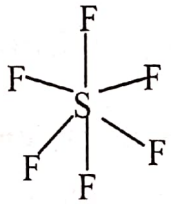
Trigonal Pyramidal



Square Pyramidal

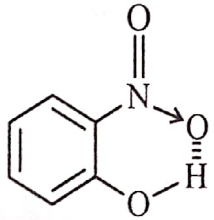


Square Planar



Octahedral

8. (c)



Intramolecular hydrogen bonding is observed in ortho nitrophenol.

(D) In the given conversion, $Cl_2(g) \rightarrow 2Cl(g)$

number of gaseous atom increases, due to which entropy increases.

Hence, Entropy will increase in case of A, C, D.

11. (a)

$2A \rightleftharpoons B + C$

$$Q_C = \frac{[B][C]}{[A]^2} = \frac{[2\times10^{-3}][2\times10^{-3}]}{[2\times10^{-3}]^2}$$

$Q_C = 1$

$Q_C > K_C$

Reaction has a tendency to go in backward direction.

$Q_C < K_C$ Reaction has a tendency to go in forward direction.

12. (c)

(a) $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$

$$K_C = \frac{[CO_2][H_2]}{[CO][H_2O]}$$

$\Delta n_g = 2 - 2 = 0$

$K_p = K_C(RT)^{\Delta n_g}$

$K_p = K_C(RT)^0$

$K_p = K_C$

(b) $2BrCl(g) \rightleftharpoons Br_2(g) + Cl_2(g)$

$\Delta n_g = 2 - 2 = 0$

$$K_C = \frac{[Br_2][Cl_2]}{[BrCl]^2}$$

$K_p = K_C(RT)^{\Delta n_g}$

$K_p = K_C(RT)^0$

$K_p = K_C$

(c) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

$\Delta n_g = 2 - 1 = 1$

$$K_C = \frac{[PCl_3][Cl_2]}{[PCl_5]}$$

$K_p = K_c (RT)^{\Delta n_g}$

$K_p = K_c (RT)^{1}$

Here, $K_p \neq K_c$

(d) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

$\Delta n_g = 2 - 2 = 0$

$$K_c = \frac{[HI]^2}{[H_2][I_2]}$$

$K_p = K_c (RT)^{\Delta n_g}$

$K_p = K_c (RT)^{0}$

Here, $K_p = K_c$

13. **(b)** Redox reactions involve change in oxidation number of the interacting species.

$\overset{0}{H_2} + \overset{0}{Cl_2} \rightarrow 2\overset{+1}{H}\overset{-1}{Cl}$ (Redox)

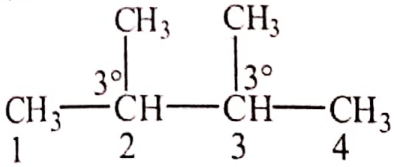
$\overset{+2}{Ba}\overset{-1}{Cl_2} + \overset{+1}{Na_2}\overset{-2}{SO_4} \rightarrow \overset{+2}{Ba}\overset{-2}{SO_4} + 2\overset{+1}{Na}\overset{-1}{Cl}$

(No change in oxidation state, hence not redox reaction)

$\overset{0}{Zn} + \overset{+2}{Cu}SO_4 \rightarrow \overset{+2}{Zn}SO_4 + \overset{0}{Cu}$ (Redox reaction)

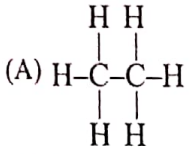
$2K\overset{+5}{Cl}O_3 + \overset{0}{I_2} \rightarrow 2K\overset{+5}{I}O_3 + \overset{0}{Cl_2}$ (Redox reaction)

14. **(a)**



IUPAC name: 2,3-dimethyl butane

15. **(a)**



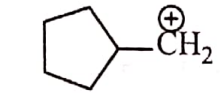
(A) $H-C-C-H$ → One σ bond

(B) $H_2C=CH_2$ → One σ-bond and one $\dot{\pi}$-bond

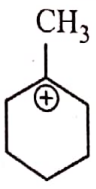
(C) C_2 → Two π-bonds

(D) $HC\equiv CH$ → One σ-bond and two π-bonds

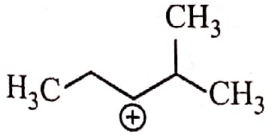
16. **(b)**



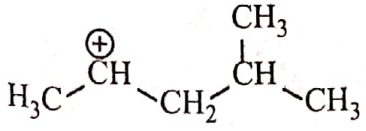
: 1° carbocation



: 3° carbocation



: 2° carbocation



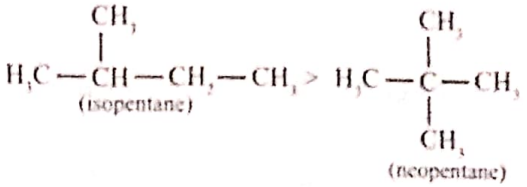
: 2° carbocation

- Stability order of carbocation : 3° > 2° > 1°.
- Hence, most stable carbocation is present in option (b).

17. **(d)** On heating, solid substances change from solid to vapour state without passing through liquid state. This purification technique is known as sublimation and is used to separate sublimable compound from non-sublimable impurities.

18. **(c)** Boiling point decreases with increase in branching as the intermolecular forces decreases

Boiling point: $CH_3-CH_2-CH_2-CH_2-CH_3$ >
(n-pentane)



(isopentane) > (neopentane)

19. **(d)** Lesser the value of K_H, more will be the solubility of gas in water.

So, solubility order:

$B(K_H = 2\times10^{-5}) > C(K_H = 35) > A(K_H = 145)$

20. **(c)**

A) $H_2O \rightarrow \frac{1}{2}O_2 + 2e^- + 2H^+$ (2F)

B) $MnO_4^- + 5e^- + 8H^+ \rightarrow Mn^{2+} + 4H_2O$ (5F)

C) Molten $CaCl_2 \rightarrow Ca^{2+} + 2e^-$ for 1.5 mole Ca^{2+} (3F)

D) $Fe^{2+} \rightarrow Fe^{3+} + e^-$ (1F)

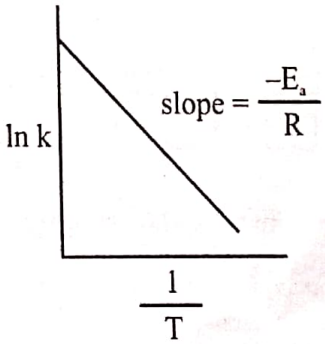
21. **(b)** Activation energy of any chemical reaction can be calculated if one knows the value of rate constant at two different temperature by given formula:

$$\log\frac{k_1}{k_2} = \frac{E_a}{2.303R}\left[\frac{1}{T_2} - \frac{1}{T_1}\right]$$

22. **(b)** Arrhenius equation is;

$$\ln k = -\frac{E_a}{R}\times\frac{1}{T} + \log A$$

Graph between ln k vs $\frac{1}{T}$ with intercept = log A and slope $= -\frac{E_a}{R}$



23. **(c)** The boiling point of hydrides of group 16 are in the order $H_2O > H_2Te > H_2Se > H_2S$.

It is due to the presence of extensive H-bonding in H_2O.

24. **(b)** Po does not show –2 oxidation state because on going down the group, electropositive nature increases.

25. **(c)** Much larger third ionisation energy of Mn (where the required change is d^5 to d^4) is mainly responsible for this. This also explains why the +3 state of Mn is of little importance.

26. (c) Spin only magnetic moment

$= \sqrt{n(n+2)}$

n = number of unpaired electrons

A	Ti^{3+}	d^1	1.73
B	Cr^{2+}	d^4	4.90
C	Mn^{2+}	d^5	5.92
D	Fe^{2+}	d^6	4.90
E	Sc^{3+}	d^0	0

$B = Cr^{2+} = 4.90$ $D = Fe^{2+} = 4.90$

27. (c)

(A) $[Co(NH_3)_5(NO_2)]Cl_2$ shows linkage isomerism. Its linkage Isomer is $[Co(NH_3)_5(ONO)]Cl_2$

(B) $[Co(NH_3)_5(SO_4)]Br$ shows ionization isomerism. Its ionization isomer is $[Co(NH_3)_5(Br)]SO_4$

(C) $[Co(NH_3)_6][Cr(CN)_6]$ shows coordination isomerism. Its coordination isomer is $[Cr(NH_3)_6][Co(CN)_6]$

(D) $[Co(H_2O)_6]Cl_3$ shows solvate isomerism. Its one of the solvate isomer is $[Co(H_2O)_5Cl]Cl_2.H_2O$

So correct option is:

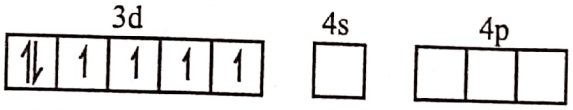
$A \rightarrow II, B \rightarrow III, C \rightarrow IV, D \rightarrow I$

28. (c)

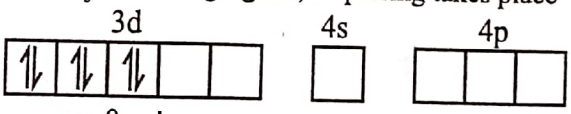
Both $[Co(NH_3)_6]^{3+}$ and $[CoF_6]^{3-}$ are octahedral complex because coordination number are six.

Electronic configuration of Co^{3+} in $[Co(NH_3)_6]^{3+}$ is

Co^{3+}: $[Ar]3d^64s^04p^0$



As NH_3 is a strong ligand, so pairing takes place

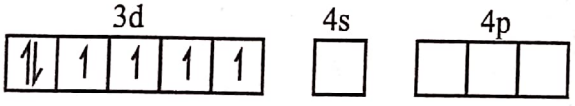


n = 0

d^2sp^3 hybridisation

No unpaired electron, so it is diamagnetic in nature Electronic configuration of Co^{3+} in $[CoF_6]^{3-}$ is

Co^{3+} : $[Ar]3d^64s^04p^0$

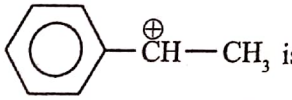


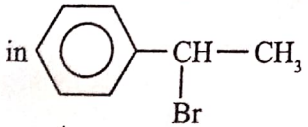
n = 4

As F^- is a weak ligand, therefore no pairing takes place

So, it is paramagnetic in nature.

29. (b)

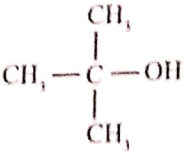
- S_N1 reaction are fastest in those compound, where the intermediate carbocation is resonance stablised.
-  is resonance stablised carbocation

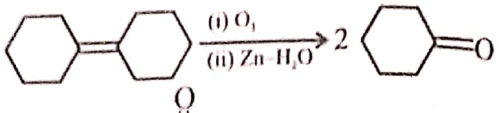
among given options. So, rate of S_N1 reaction will be fastest in 

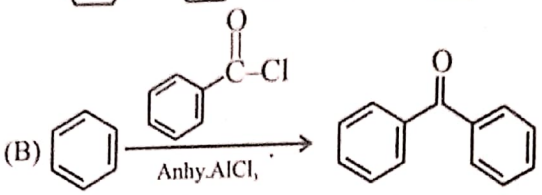
30. (b) 3° alcohols react with Lucas reagent instantaneously.

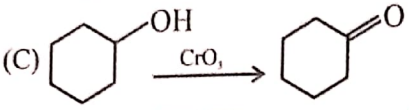
2° alcohols react with Lucas reagent after 5 minute.

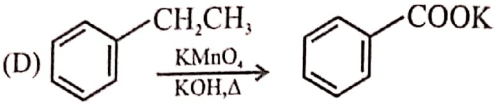
1° alcohols do not react with Lucas reagent at ordinary temperature.

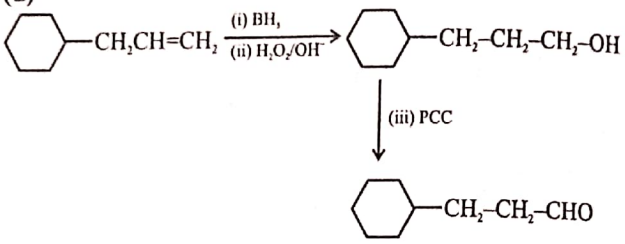
 it is tertiary alcohol which give Lucas test instantaneously.

31. (a) (A) 

(B) 

(C) 

(D) 

32. (d) 

33. (c) Fehling's solution 'A' is aqueous copper sulphate.

34. (c)

- Aniline does not undergo Friedel-Craft reaction due to salt formation with anhy. aluminium chloride (the lewis acid) which is used as a catalyst.
- Gabriel synthesis is used for the preparation of aliphatic primary amines only. Aromatic primary amines cannot be prepared by this method because aryl halide do not undergo nucleophilic substitution reactions.

35. (a) Despite having the aldehyde group, glucose does not give Schiff's test and it does not form the hydrogensulphite addition product with $NaHSO_3$.

36. (d)

Element	Percentage composition	Atomic mass	Atomic ratio of atoms	Simplest ratio of atoms
A	32%	64	$\frac{32}{64} = 0.5$	$\frac{0.5}{0.5} = 1$
B	20%	40	$\frac{20}{40} = 0.5$	$\frac{0.5}{0.5} = 1$
C	48%	32	$\frac{48}{32} = 1.5$	$\frac{1.5}{0.5} = 3$

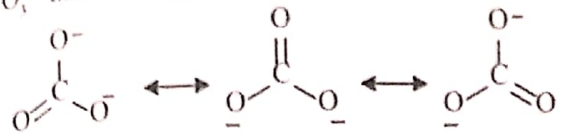
Hence, empirical formula is ABC_3.

37. (b)

- Dipole Moment:

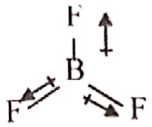
(μ_{net} = 4.9×10^{-30} C m) (μ = 0.8×10^{-30} C m)

- CO_3^{2-} has three canonical forms.



- Two resonating structures can be drawn for ozone.

- BF_3 has trigonal planar structures. Its net dipole moment is Zero.



μ = Zero

38. (d) $W = -2.303nRT \log\left(\frac{P_1}{P_2}\right)$

$= -2.303\times1\times2\times298\times\log\left(\frac{20}{10}\right)$

$= -2.303\times2\times298\times0.301$

$= -413.14$ Calories

39. (b)

$$2NO(g) \rightleftharpoons N_2(g) + O_2(g)$$

At t = 0 0.1 M – –

At time = t $(0.1-0.1\alpha)$M $\left(\frac{0.1\alpha}{2}\right)$M $\left(\frac{0.1\alpha}{2}\right)$M

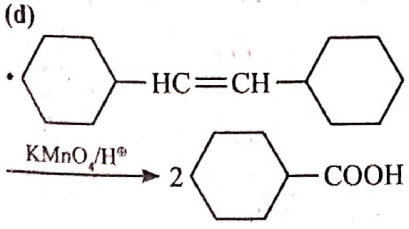
$$\therefore K_c = \frac{3\times10^{-3}\times4.2\times10^{-3}}{(2.8\times10^{-3})^2} = \frac{\frac{0.1\alpha}{2}\times\frac{0.1\alpha}{2}}{(0.1-0.1\alpha)^2}$$

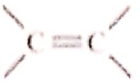
$$1.6 = \frac{\left(\frac{0.1\alpha}{2}\right)^2}{(0.1-0.1\alpha)^2}$$

$$1.27 = \frac{\left(\frac{0.1\alpha}{2}\right)}{0.1-0.1\alpha}$$

$\alpha = 0.717$

40. (d)



 Will be completely oxidized in presence of acidified $KMnO_4$ into carboxylic acid

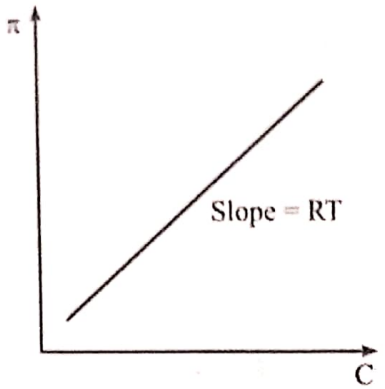
41. (c) $\pi = CRT$

$\therefore$ slope = RT = 25.73 L bar mol^{-1}

$\therefore T = \frac{25.73}{0.083}$

= 310K

= 37°C



42. (d)

$W = Z\times i\times t$

$= \frac{63}{96487\times2}\times9.6487\times100$

$= 0.315$g

43. (c)

$$\log\left(\frac{k_{330}}{k_{300}}\right) = \frac{E_a}{2.303R}\times\left[\frac{330-300}{300\times330}\right]$$

Given: $\frac{k_{330}}{k_{300}} = 4$

$$\therefore \log 4 = \frac{E_a}{2.303R}\times\frac{30}{300\times330}$$

$$\therefore E_a = \frac{0.602\times2.303\times8.314\times300\times330}{30}\text{ J/mol}$$

= 38037.7 J/mol

= 38.0377 kJ/mol

$\simeq$ 38.04 kJ/mol

44. (c)

$Gd^{3+}_{(Z=64)}$: $[Xe]4f^7$ (7 unpaired e$^-$)

$\therefore Eu^{3+}_{(Z=63)}$: $[Xe]4f^6$ (6 unpaired e$^-$)

$\therefore Pm^{3+}_{(Z=61)}$: $[Xe]4f^4$ (4 unpaired e$^-$)

$\therefore Sm^{3+}_{(Z=62)}$: $[Xe]4f^5$ (5 unpaired e$^-$)

$\therefore Ce^{4+}_{(Z=58)}$: $[Xe]4f^0$ (No unpaired e$^-$)

$\therefore Yb^{2+}_{(Z=70)}$: $[Xe]4f^{14}$ (No unpaired e$^-$)

$\therefore Ce^{3+}_{(Z=58)}$: $[Xe]4f^1$ (1 unpaired e$^-$)

47. (b)

$3ROH + PCl_3 \rightarrow 3RCl + H_3PO_3$

(A)

$ROH + PCl_5 \rightarrow RCl + HCl + POCl_3$

(B)

Hence, A : H_3PO_3 and B : $POCl_3$

50. (c) Below given are the cations and their corresponding group as per qualitative analysis.

Cation	Group
Cu^{2+}	2
Al^{3+}	3
Co^{2+}	4
Ba^{2+}	5
Mg^{2+}	6

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